MANUAL OF
TIDAL PREDICTIONS

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GLASGOW

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MANUAL OF TIDAL PREDICTION

1. Tides are fluctuations in the mean level of the sea by the

Manual of Tidal Prediction, First Edition, 1940.

ERRATA.

PAGE 66. Height of High Water for Helgoland *should read* 8·8 not 6·9.

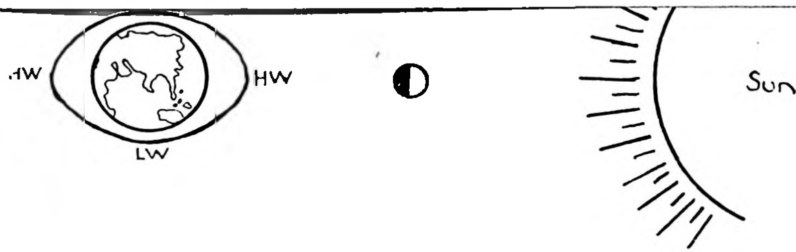
PAGE 67. Paragraph 5 *read* two weeks not four weeks.

PAGE 87. Answer, Q. 4. $\theta = 56°$, interval 2 hr. 2 min. Standard time 08 hr. 07 min., L.M.T. 07 hr. 39 min.

PAGE 88. Question 6, line 1, *delete* range.

PAGE 88. Question 9 *should read* $\times 0·4$ not 0·4.

PAGE 107. Appendix. For Time Meridian for Helgoland *read* Time Meridian 15°E. (Zone — 1.)



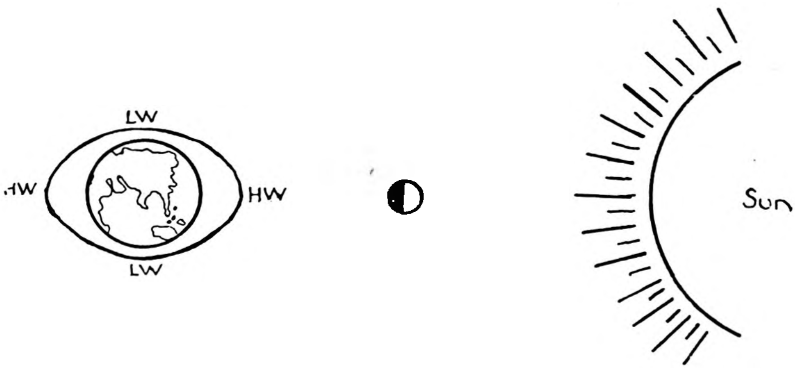
Sun and Moon in conjunction. "New Moon."

MANUAL OF TIDAL PREDICTION

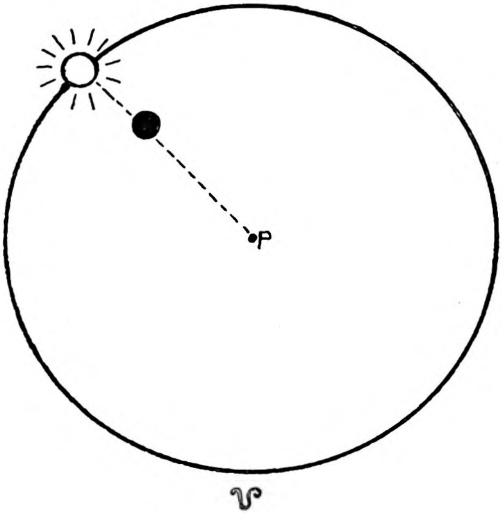
1. Tides are fluctuations in the mean level of the sea by the gravitational attractions of the Moon and Sun. Although tides are very important to shipping they represent a very small change of level and never amount to one-millionth of the Earth's diameter. Because of this, all diagrams to illustrate tides have to show grossly exaggerated tidal effects.

2. The body having the greatest pull is the Moon, which exerts about $2\frac{1}{4}$ times the attractive force of the Sun. This is because the Moon is about 400 times nearer the Earth than is the Sun.

3. When the Moon and Sun are over the same meridian their attractions are combined and we get a maximum height of tide called "spring tide". To do this the Sun and Moon must be in conjunction (both have the same Right Ascension) and the Moon will be "new" or "changing".

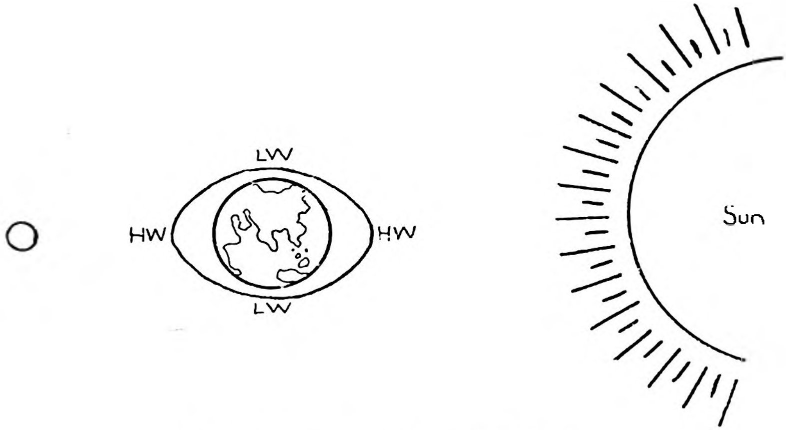


Sun and Moon in conjunction. "New Moon."

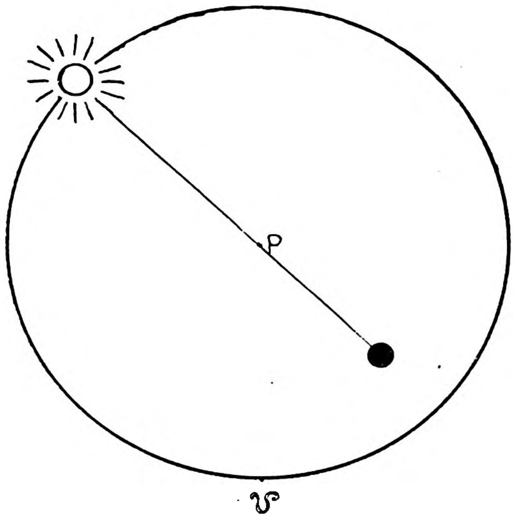


Looking down on the celestial sphere. P is the N. Pole. ♈ is the First Point of Aries. The Sun and Moon have the same Right Ascension, *i.e.* distance along the equinoctial measured Eastwards from Aries. The circle is the equinoctial.

4. Whenever a tide is raised under the Sun or Moon, or both, a tide of similar height is raised at the opposite point on the Earth. For example, if the Moon or/and Sun are acting on a point in Long. 90° E., Lat. 10° N., then a tide is also being raised in Long. 90° W., and Lat. 10° S. The reason for this is often not understood, but an explanation is given in the Appendix and so we will take it for granted that this is so. At any moment, therefore, we have two diametrically opposite places where there is high water. At right angles to the line joining these places we can draw a line between diametrically opposite places where there is low water. The net result of this is that we get spring tides when the Sun and Moon are in opposition (12 hours apart in Right Ascension) and the Moon is "full", exactly as we do when they are in conjunction.



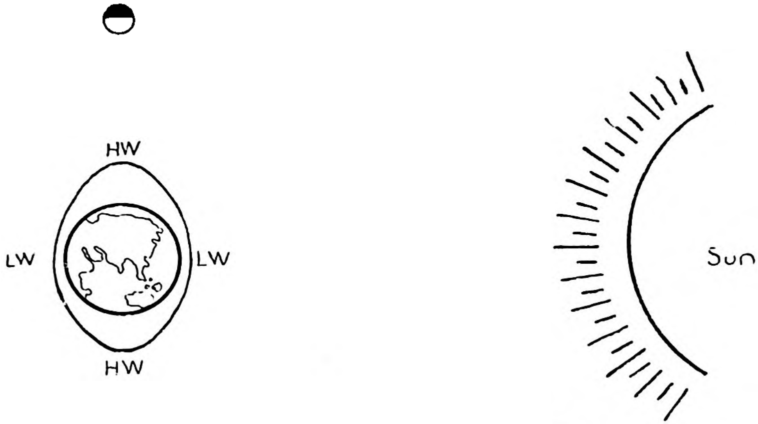
Sun and Moon in opposition. "Full Moon."



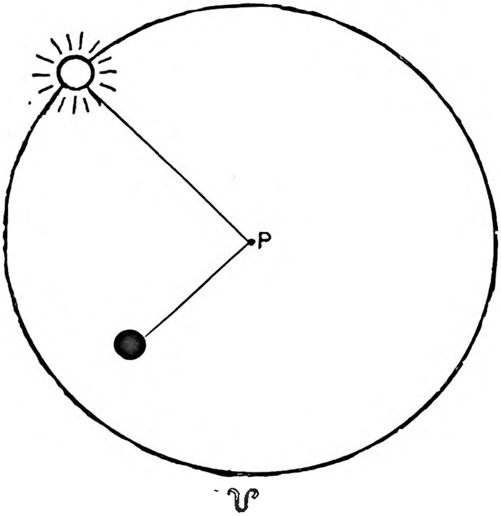
The Right Ascension of the Sun and Moon differ by 12 hours.

5. If the Moon moved at the same speed as the Sun she would never get away from conjunction and we should always have

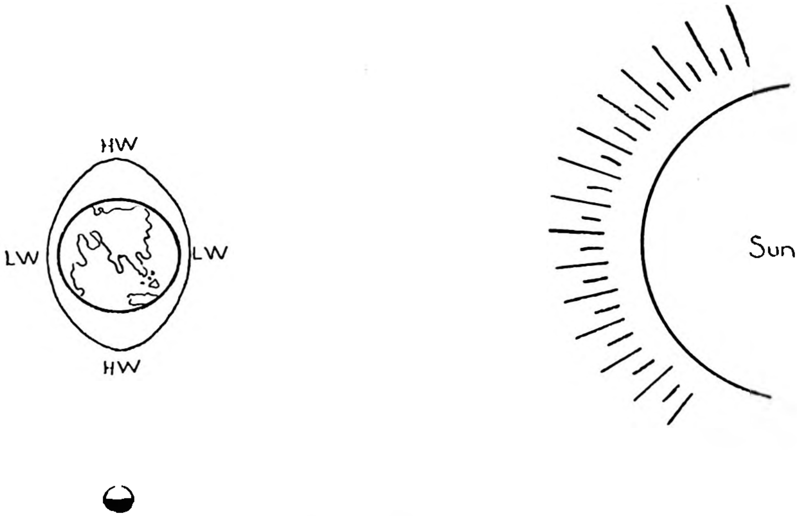
spring tides. But she moves $12\frac{1}{2}°$ farther away from the Sun every day, and in a little more than a week she is 90° away from the Sun and exerting her attraction on a position where the Sun is trying



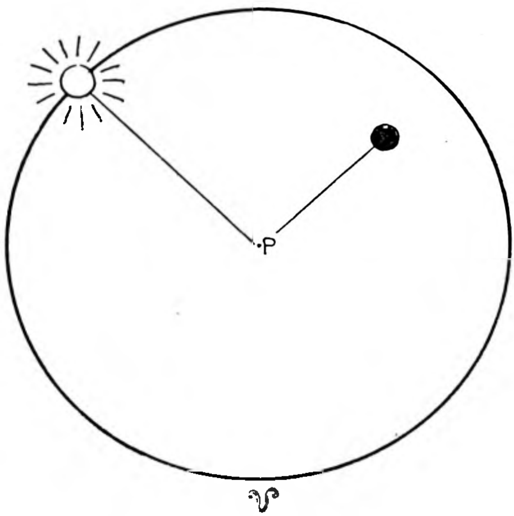
Moon at Quadrature. "First Quarter." Neap Tides.



Moon's Right Ascension is 6 hours greater than Sun's.



Moon in Quadrature. "Third quarter." Neap Tides.



Moon's Right Ascension is now only 6 hours less than Sun's.

to cause a low water. Similarly, the Moon is trying to cause a low water where the Sun is making a tide. This happens, of course, when the Moon is on her 1st and 3rd quarters—which is termed "quadrature". The change of sea level is then least, and the tides are called "neap tides".

6. Intermediate between springs and neaps we have tides that are composed partly of the Moon's tide and partly of the Sun's tide. They are always less in height than spring tides, and always higher than neap tides. This is because spring tides=Sun's tide+Moon's tide, and Neap tides=Moon's tide alone. These intermediate tides have this peculiarity: when the Moon is in her first and third quarters the interval between tides is less than the average; when she is in her second and fourth quarters the interval is longer than the average.

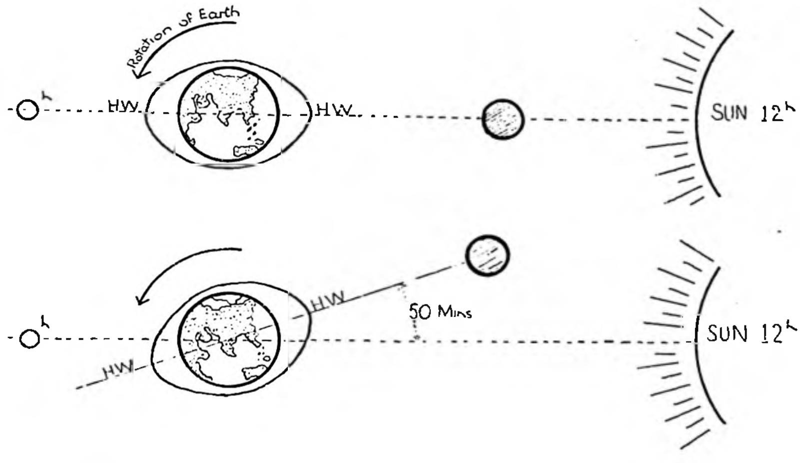
When the interval is shorter we say the tide is "priming"; when it is longer we say the tide is "lagging". We thus see that the position of the Moon with reference to the Sun affects both the height and time of high water. The angular distance between these two bodies is the cause of the phasing of the Moon, and so we term these changing levels and changing intervals the "phase inequality of heights" and the "phase inequality of times".

7. To sum up: a little consideration of the foregoing will show that, for the purposes of this explanation, we may broadly assume that there is always a small heap of water under the Sun; and another heap of water, $2\frac{1}{4}$ times this height, under the Moon. As the Moon goes round the sky she takes her heap of water with her. Sometimes it piles itself on the Sun's tide—spring tides; sometimes it is at the Sun's low water—neap tides, and between these it is partially combined with the Sun's tide. Also, at the opposite points of the Earth there are heaps of water similar to those under the Sun and Moon.

8. As the Earth turns on its axis any meridian will be carried through these heaps of water, and the two higher heaps will be the high waters for that particular day. The highest heaps always lie under the Moon, and so the transit of a meridian across the Moon—which is the same thing as the Moon's transit across the meridian—will be the vital factor in determining the height and time of high

water. In view of this fact we will now discuss the Moon's motion in the heavens.

9. If, on any particular day, the Sun and Moon have the same Right Ascension these two bodies are said to be "in conjunction", and our meridian will cross them both at the same time. As it is noon when the Sun is in transit, the time of the Moon's transit, when she is "new", will obviously be 12 hr. also. As our meridian swings past her it will go under her heaps of water and we shall thus get our tide. In another 12 hours we might expect to pass into the heap of water on the opposite side of the Earth, but when we get there we find that the heap has shifted further along and it takes us another 25 minutes or so to come to the high water. The reason for this is that, while our meridian has been turning through 180° the Moon has moved about 6° away from the Sun, and taken her heaps away with her. Consequently, when we get back to the Sun (12 hr. on the next day) the Moon is now nearly 13° away from the Sun, and we shall not pass into her high water until 12 hr. 50 min.



This continues day after day until the Moon gets back to conjunction again in about 29½ days; and then starts all over again. This is why the time between high waters is generally about 12 hr. 25 min. and a "tidal day" is about 24 hr. 50 min.—which is identical with a lunar day.

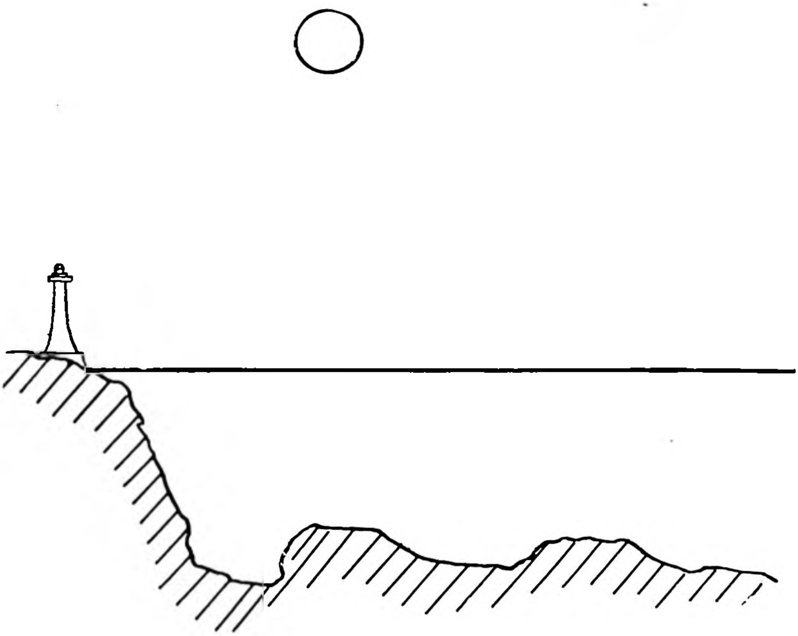
10. Although the times of high waters will depend on the time of Moon's transit we know that spring tides will always depend on the Sun's transit. This is because the Sun and Moon are in the same place at new Moon, and directly opposite at full Moon (see par. 3). Theoretically we should get spring tides at 00 hr. and 12 hr., but in practice this is not so. This is because we have been imagining a smooth globe covered with a frictionless fluid; which is very far from being the case. As a result of the Earth having considerable areas of land, varying depths of water, and water having a definite amount of friction in itself, we find that there is a distinct time interval between the transit of the Moon and Sun and our arrival at the tidal heap, or undulation.

11. The time interval mentioned above has been observed when the Moon was new and full at more than 8000 positions on the Earth. These intervals have been tabulated as the "lunitidal interval" at a given place. Sometimes it is called the "Establishment of the Port", the "H.W.F.&C." or just the "interval". In any case it simply represents the actual time that elapses between the new or full Moon crossing the meridian at a given place and the appearance of the spring tide there.

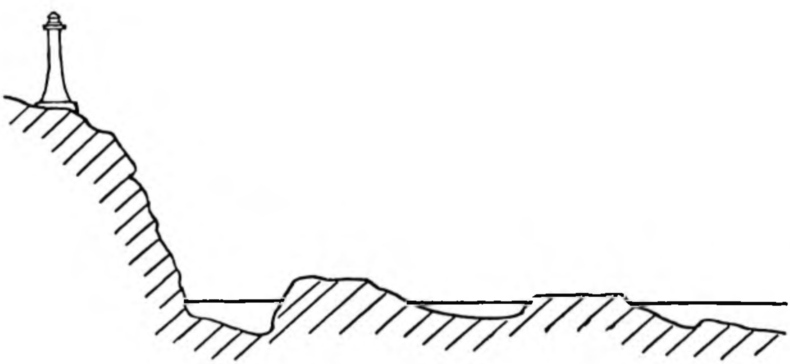
The Moon crosses the meridian at 12 hr. (local time) when new and at 00 hr. (local time) when full; thus the "interval" is exactly the same as the local civil time of spring high water. Make sure you understand this.

As an example, we will take Newcastle-on-Tyne. The lunitidal interval (H.W.F.&C.) is given as 3 hr. 13 min. At full Moon the time of Moon's transit is 00 hr. (L.M.T.) and high water will occur at 03 hr. 13 min. At new Moon the time of Moon's transit is 12 hr. 00 min.; and 3 hr. 13 min. added to this gives 15 hr. 13 min. (3 hr. 13 min. p.m.) These are the spring tides (approximately).

12. Due to "priming" and "lagging" of the tide (see par. 6) the interval between the Moon's transit and the formation of H.W. varies between spring tides. If it did not do so we could always add the H.W.F.&C. of the place to the time of Moon's transit and so get time of high water. But as it does vary we have to make allowances for the variation. When we wish to find the time of high water we must, therefore, make adjustments for "the phase inequality of times". With certain types of tides this may be done fairly simply.

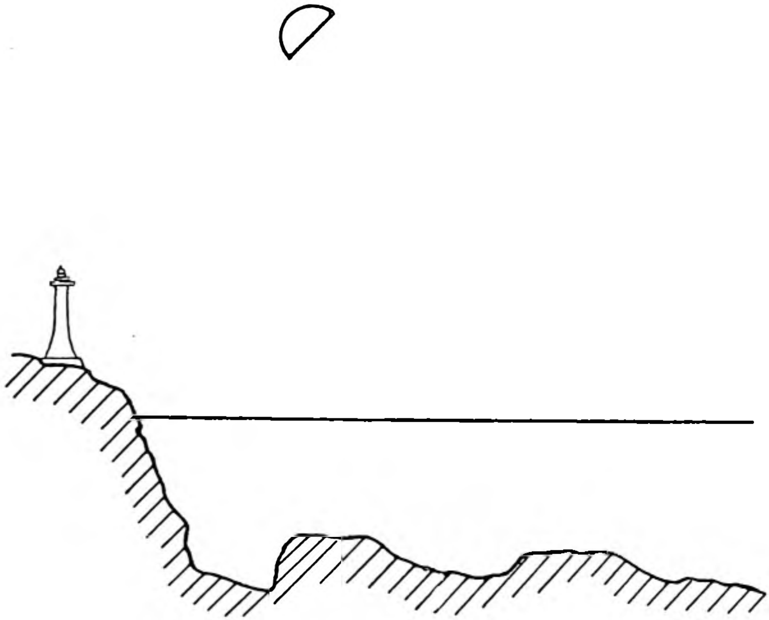


Full Moon. High Water Spring Tides.



New or Full Moon. Low Water Spring Tides.

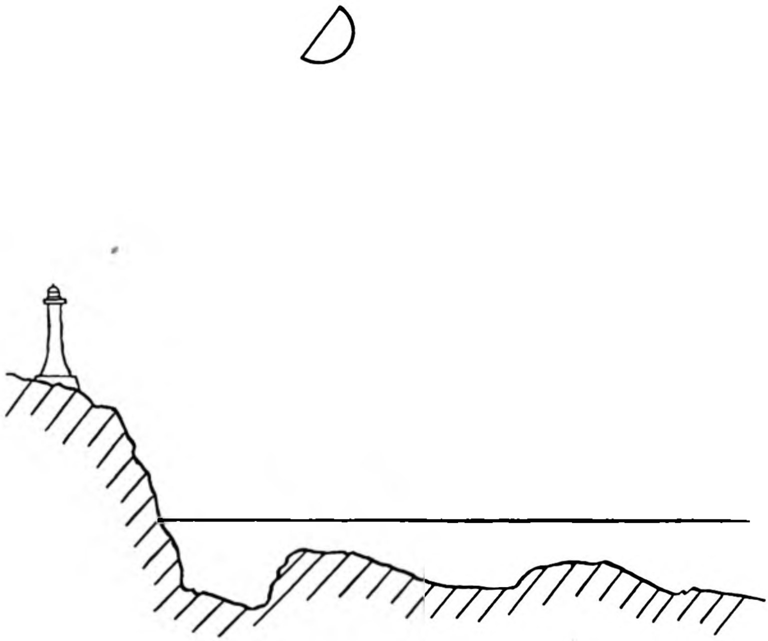
13. At spring tides we have a maximum height of high water; at neap tides we have a minimum height of high water. These heights at springs and neaps are tabulated for many ports, and we know that the high water will rarely be less than the neap figure, and rarely more than the spring figure. Between springs and neaps the height of high water will be between the spring and neap heights; and, with certain types of tides, we can calculate fairly easily how much the high water will be less than the spring height. In other



Moon in Quadrature. Third Quarter. High Water Neap Tides.

words, we can calculate the "phase inequality of heights". Neither the phase inequality of heights nor the phase inequality of times can be used for all ports, and so discretion has to be exercised in deciding the method by which we are to find the time and height of high water at a place. For the time being we consider places that

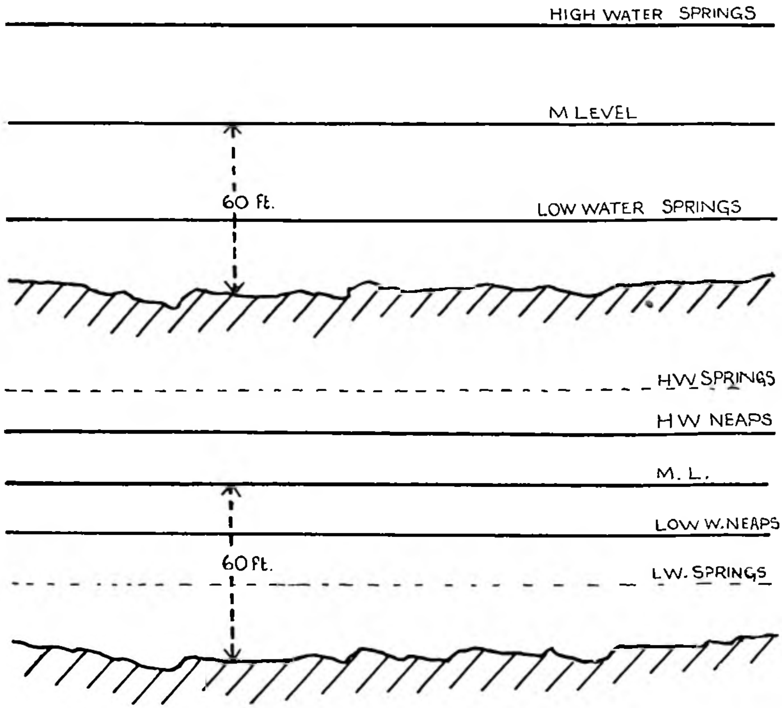
can be dealt with in this manner; and we usually refer to them as "places where the tide is semidiurnal and regular".



Moon in Quadrature. First Quarter. Low Water Neap Tides.

14. So long as tides are regular we can get a fairly good idea of how much the tide has risen at any given time between high and low waters. To learn how this is done we must first understand what is meant by "mean tide level". This is the half-way line between the high water of any tide and its own low water. This mean level is the same for all tides, spring, neap, or intermediate. That is to say, if there is a depth of 60 ft. at half tide at neaps there will be 60 ft. at half tide at springs—or any other tide. The reason for this is that the tide falls below its mean level just the same amount

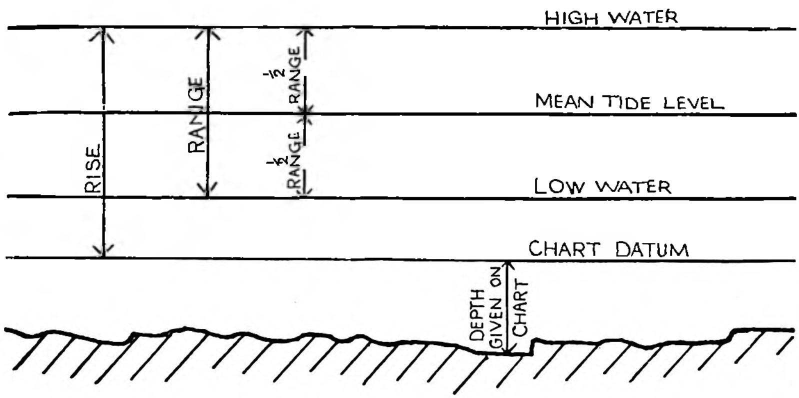
as it rose above it (approximately). The depths at high and low waters will, however, vary continually.



15. What we usually want to know is the amount of water above the bottom of the sea. When we look on the chart we find a figure representing a certain depth (usually in fathoms). Is this the depth at high or low water? The answer is: Low water. The next question is: Is this the low water at springs, or neaps? The answer may vary, but on British charts it is nearly always the low water at ordinary spring tides (L.W.O.S.T.) For this reason this level is termed "chart datum", and if some *other* level is used it will be stated on the chart. Foreign charts may use different levels —but British charts of foreign waters will say what that level is if it is not L.W.O.S.T.

16. The advantage of using L.W.O.S.T. as a datum is that we can nearly always count on the charted depth as a minimum amount of water; and if there is any tide at all it will be extra to the charted depth. But sometimes the tides are extraordinary, and we may get a low water that goes below chart datum. In this case we have to subtract the amount it went below chart datum from the depth on chart. We must always be on the look-out for this.

17. The amount a tide rises above *chart datum* is termed its "rise". The amount it rises above its *low water* is termed its



"range". The amount it rises above or falls below *mean tide* level is termed its "half range". The time interval between high and low waters of any tide is called its "duration".

These terms must be thoroughly understood, and care must be taken not to confuse "range" with "rise".

18. We saw, in paragraph 9, that the approximate time for the tide to go from one low water to the next—or from one high water to the next—is 12 hr. 25 min. As a "duration" is the time between high and low waters it must be half a tidal period, and can be considered to be about $6\frac{1}{4}$ hr. We have already seen that this period may vary (par. 12), but there may be other irregularities. For the present, however, we will content ourselves by saying that duration is $6\frac{1}{4}$ hr. (nearly).

THE TIDE TABLES.

19. The Tide Tables published by the Admiralty are in three parts but four books: Part I being in two sections, A and B. These four books of Admiralty Tide Tables are generally written as A.T.T. IA; A.T.T. IB; A.T.T. II, A.T.T. III. We shall follow this practice.

20. A.T.T. IA and IB give daily tidal predictions for all the principal ports and positions in the world. Section A covers the British Isles and the North and West Coasts of Europe: Section B covers the remaining waters. It should be noted that the page numbers in Section B follow consecutively on those in Section A. For instance, the first page of Section B (1939) is 140, and the last page of Section A (1939) is 139.

21. The information given in Part I includes the latitude and longitude of the place, and the times of each high water, the times of each low water, the height at each high water and the height at each low water, for every day throughout the year. At the end of the book are supplementary tables to assist us in calculating the height of the tide at any moment between high and low waters. The times are shown in "4 figure notation", that is, 9 hr. 25 min. A.M. is printed 0925, while 9h. 25m. P.M. is printed 2125. The first two figures always represent the hour (from 00 to 23) and the last two figures represent the minutes (from 00 to 59). Heights are given in feet and decimals of a foot; 8·5 would equal $8\frac{1}{2}$ feet, or 8 ft. 6 ins.

22. At the bottom of each page we have some very important information given in small print, the most important being the time that is used in the predictions. It differs, of course, for different places, but, apart from that, it also varies in the kind of time adopted. In most cases the standard time is zone time, but there are many ports where the standard time used is not zone time. In all cases we are given the meridian on which the time is based, and also the correction to be applied to this time to get G.M.T.

23. The sequence of the places given in both parts is arranged geographically. For the student this may be rather confusing, but for the navigator it is infinitely more useful than a sequence based in alphabetical order. In Part IA we start from Devonport and go eastward along the South Coast of England, along the East

Coasts of England and Scotland, Orkneys, Hebrides, West Coast of Scotland, England and Wales. Thence to West Coast of Ireland, and around it in an anti-clockwise direction. From there we go to the North Coast of Europe and come South down to Gibraltar and also Freetown (Sierra Leone.)

24. In Part IB we go from Gibraltar along the South Coast of Europe back along the North Coast of Africa and down the West Coast. From there we go to the Southern end of America, and up the East Coast of that Continent. Thence we come back to the South and East Coasts of Africa and follow the coast of Asia round to the North of China, thence to Japan, thence to Australia, Pacific Islands and Pacific coast of the American Continent. This makes it difficult to quickly pick out a particular place, and until one is thoroughly used to the lay-out of the Tide Tables it is best to consult the alphabetical list of ports which will be found in the *front* of the book. Each section (A and B) has this list of all ports in *both* sections, but the ports in the section consulted are in large italic capitals. The ports that are in the other section are in small capital letters. The two ports that are in both sections are in heavy type.

25. All ports with fully predicted tides are Standard ports. Looking through these tables we may note many peculiarities. Sometimes there is only one tide in the day. Sometimes one tide in a day may have a large range, while the other tide has a very small range. Very often we see low water depths with an asterisk, thus * 1. 2. This means that the amount tabulated is *below chart datum* and must therefore be deducted from charted depth. These asterisks are very plentiful in U.S.A. ports on the Eastern seaboard. The reason for this is that the U.S.A. uses a chart datum based on *mean* low water and not L.W.O.S.T. (par. 15); consequently all spring tides will fall below chart datum.

Careful perusal of the tables will bring to light many instances where the succession of high and low waters and their respective heights is so irregular and erratic that they appear to have no underlying law. We shall deal with this matter later on and we will only remark now that it is not only impossible but ridiculous to consider the possibility of basing the times or heights of tides on any one method unless we have far more information than we have yet considered.

STANDARD TIME.

26. Standard time is the clock time used in a given country, or area, for civil purposes. Its purpose is twofold: on the one hand it keeps all people in a specified group reckoning by the same clock time; on the other hand the standard time is so arranged that there is a fairly close relationship between this time and the position of the Sun.

27. Local time would be no good for civil purposes because it changes with longitude. In the British Isles, for instance, any place would have a time 5 minutes different from another place 40 miles East or West of it. To avoid confusion, we therefore use a standard time, based on the meridian of Greenwich (long. 0°), throughout the British Isles. In a similar manner other countries select an appropriate meridian from which to reckon a time of their own, and in some cases for a part of their country—if it is large.

28. In the majority of cases these standard time meridians are multiples of 15° of longitude East and West of Greenwich. This has the advantage of making standard time a complete number of hours different from Greenwich mean time. Some countries, however, do not do this. Holland, for example, uses the meridian of Amsterdam (4° 53′ E.) as a time meridian, and her time is thus 19 min. 32 sec. different from G.M.T.

29. Standard time being the national, or recognised, clock time at any place it stands to reason that the local tide tables will be kept to this time. Furthermore, because a zone time meridian may pass through a country it stands to reason that no country would keep two different times rather than ignore a zone time meridian. Consequently, standard time may or may not be the same as zone time, but it will rarely be very much different.

30. A.T.T.I. always specifies the time meridian at any port, and always specifies the constant to turn S.T. (standard time) into G.M.T. For Kem, for instance, we have: Time meridian: 30° E. (zone − 2.) This tells us that the clock time at Kem is based on local mean time in Long. 30° E. and that we must subtract 2 hr. from this standard time to get G.M.T. Note that Kem is in Long. 34° 47′ E.

31. We may also get this expressed in a different way. For Flushing we are told: Time meridian 4° 53′ E. (00hr. 20m. fast). This method is always followed when the standard time is different from the zone time for that place. It is most important to remember that when a sign is put before the zone or standard time constant it shows what must be done with this constant *to turn standard time into G.M.T.* as + meaning add, and − subtract. In the case of "fast" or "slow" the amount of time indicated is the error on G.M.T.; "fast" meaning greater than G.M.T. and "slow" meaning less.

Owing to the direction of the Earth's rotation being from west to east (——→) meridians east of the observer come to the Sun earlier, while those meridians west of the observer reach the Sun later so that the rhyme—

"Standard time is best when ship is west.
Standard time is least when ship is east."

is a natural continuation of the well-known Greenwich and ship time rhyme. In this case, however, it must be clearly understood that the name or amount of longitude of ship and standard meridian is immaterial: all that does matter is whether the ship is to the westward or eastward of the standard meridian.

TO CORRECT THE TIME OF CAST UP TO STANDARD TIME.

Where the Greenwich Meridian is the Standard Meridian.

Worked Example 1. (First Type.)

Required standard time of cast of a sounding taken January 10 at 11 hr. 10 min. standard time off Portsmouth?

As the cast is already stated as standard time no alteration is necessary. Standard time of cast 11 hr. 10 min. or 1110.

Worked Example 2.

Required standard time of cast of a sounding taken February 4 at 06 hr. 08 min. G.M.T. off Portsmouth?

The time meridian of Portsmouth is Greenwich (zone 0) hence standard time is Greenwich time. Standard time of cast=06 hr. 08 min. or 0608.

Worked Example 3.

Required standard time of cast of a sounding taken January 1 at 17 hr. 06 min. L.M.T. off Portsmouth?

The standard time meridian of Portsmouth is Greenwich Longitude 0°. The longitude of Portsmouth is 1° 07′ W. The difference of longitude is therefore 1° 07′ W'ly=4 min. 28 sec., say 4 min. Now the ship is west of the standard meridian therefore (see Par. 31) standard time is 4 min. ahead of L.M.T., which makes standard time of cast 17 hr. 10 min. or 1710.

Worked Example 4.

Required standard time of cast of a sounding taken July 17 at 06 hr. 06 min. B.S.T. (British summer time) off Portsmouth?

British summer time is 1 hr. ahead of G.M.T. Therefore G.M.T. of cast is 05 hr. 06 min. As the Greenwich meridian is the time meridian of Portsmouth, Standard time of cast is 05 hr. 06 min. or 0506.

Examples for Practice No. 1.

Required standard time of cast.

1.	January	12 at 10h	17m	G.M.T.	Devonport
2.	February	4 at 04	06	L.M.T.	Devonport
3.	March	10 at 16	06	Standard time	Devonport
4.	July	4 at 15	00	B.S.T.	Devonport
5.	February	10 at 03	10 P.M.	L.M.T.	Devonport
6.	May	22 at 10	00	L.M.T .	Dover

Where the Greenwich Meridian is not the Standard Meridian.

Worked Example 1. (Second Type.)

January 14 at 03 hr. 00 min. G.M.T. off Helgoland?

The standard meridian for Helgoland is 15° E. (zone —1), *i.e.* 1 hour (fast) ahead of Greenwich time. Standard time of cast 04 hr. 00 min. or 0400.

Worked Example 2.

February 4 at 01 hr. 06 min. L.M.T. off Helgoland.

Longitude of standard meridian	15° 00′ E.
Longitude of Helgoland	7 54 E.
Diff. of longitude	7° 6′ W'ly=28 min. W'ly

The ship is west of the standard meridian hence standard time is best!

Standard time of cast 01 hr. 34 min. or 0134.

Worked Example 3.

April 25 at 10 hr. 00 min. G.M.T. off Hoek Van Holland?

Here standard time is not a zone time but is a special standard time 20 min. fast (or ahead) of Greenwich time.

Hence standard time of cast is 10 hr. 20 min.

Worked Example 4.

November 11 at 11 hr. 00 min. L.M.T. off Sierra Leone.

Longitude standard meridian	15° 00′ W.
Longitude Sierra Leone	13 14 W.
Diff. of longitude	1 46 E'ly. =7 min. E'ly

The ship is to the east of the standard meridian, hence standard time is least!

Standard time of cast 10 hr. 53 min.

Examples for Practice No. 2.

Required standard time of cast.

1.	January 11	at	noon		G.M.T.	Helgoland
2.	February 3	at	20h	00m	L.M.T.	Helgoland
3.	June 16	at	midnight		Standard time	Hoek Van Holland
4.	May 21	at	23	45	G.M.T.	Hoek Van Holland
5.	July 14	at	06	00	L.M.T.	Hoek Van Holland
6.	September 20	at	10	00	G.M.T.	Sierra Leone
7.	November 10	at	12	10	L.M.T.	Sierra Leone
8.	December 12	at	06	00	Zone time (+1) off	Sierra Leone

CHOOSING THE TIDE.

To take out the required times of high and low water in order that one shall be the first time before and the other the first time after the standard time of cast.

Worked Example 1. (First Type.)

January 1 at 3 hr. 00 min. standard time off Devonport?

EXTRACT FROM TIDE TABLES.—A.T.T. I. See Appendix.

High Water			Low Water		
Time		Ht.	Time		Ht.
h	m	Ft.	h	m.	Ft.
00	30	12·3	06	40	4·9
13	00	12·6	19	20	4·2

It will be seen from the above extract that the first tide of the day was a high water at 00 hr. 30 min.; this tide fell to low water at 06 hr. 40 min. The tide now commences to rise until it is high water for the second time this day at 13 hr. 00 min. The tide now falls until low water at 19 hr. 20 min. The tide is now rising again towards a high water the following morning.

The required times are 00 hr. 30 min. and 06 hr. 40 min. (tide falling).

Worked Example 2.

January 1 at 08 hr. 00 min. standard time off Devonport?

The required times are 06 hr. 40 min. and 13 hr. 00 min. (tide rising).

Worked Example 3.

January 1 at 16 hr. 00 min. standard time off Devonport?

The required times are 13 hr. 00 min. and 19 hr. 20 min. (tide falling).

Worked Example 1. (Second Type.)

January 7 at 03 hr. 00 min. standard time off Devonport.

EXTRACT FROM TIDE TABLES.—A.T.T. I.

High Water			Low Water		
Time		Ht.	Time		Ht.
h	m	Ft.	h	m	Ft.
06	38	17·1	00	33	0·5
19	04	16·8	12	58	0·1

The first tide to-day is a low water at 00 hr. 33 min. which rises to high water at 06 hr. 38 min. The tide now falls to low water at 12 hr. 58 min. and then rises to high water at 19 hr. 04 min?

The required times are 00 hr. 33 min. and 06 hr. 38 min. (tide rising).

Worked Example 2.

January 7 at noon standard time off Devonport?

The required times are 06 hr. 38 min. and 12 hr. 58 min. (tide falling).

Examples for Practice 2A.

Required the times of high and low water for the following casts:—

1. January 2 at 03 hr. 17 min. standard time off Devonport.
   Ans. 01 hr. 43 min. and 07 hr. 58 min. falling tide.
2. May 21 at 11 hr. 00 min. standard time off Dover.
   Ans. 07 hr. 33 min. and 12 hr. 23 min. rising tide.
3. January 11 at 06hr. 00 min. standard time off Devonport.
   Ans. 03 hr. 35 min. and 09 hr. 39 min. rising tide.
4. May 19 at 13 hr. 00 min. standard time off Dover.
   Ans. 11 hr. 05 min. and 18 hr. 27 min. falling tide.
5. May 18 at 20 hr. 00 min. standard time off Dover.
   Ans. 17 hr. 47 min. and 22 hr. 44 min. rising tide.

Worked Example 1. (Third Type.)

January 2 at 01 hr. 00 min. standard time off Devonport?

EXTRACT FROM TIDE TABLES. See Appendix.

	High Water			Low Water		
	Time		Ht.	Time		Ht.
	h.	m.	Ft.	h.	m.	Ft.
January 1	00	30	12·3	06	40	4·9
	13	00	12·6	19	20	4·2
January 2	01	43	12·7	07	58	4·3
	14	16	13·1	20	36	3·2

The required times are January 1 19 hr. 20 min. and January 2 01 hr. 43 min. rising tide.

(We are on a tide which starts on January 1 and finishes on January 2.)

Worked Example 2.

January 1 at 22 hr. 00 min. standard time off Devonport?

The required times are January 1 at 1920, and January 2 at 0143.

Worked Example 3.

January 6 at 03 hr. 00 min. standard time off Devonport?

EXTRACT FROM TIDE TABLES.

	High Water		Low Water	
	Time	Ht.	Time	Ht.
	h. m.	Ft.	h. m.	Ft.
January 5	0457	15·3	1117	1·0
	1724	15·4	2344	0·8
January 6	0547	16·4	—	—
	1815	16·3	1208	0·4

The required times are 23 hr. 44 min. (January 5) and 05 hr. 47 min. (January 6). If the columns in A.T.T. I. are studied carefully it will be seen that for a number of days H.W. is the first tide of the day and then for a nearly similar number of days L.W. becomes the first tide of the day.

The day before the "change over" takes place only three times of high and low water are tabulated.

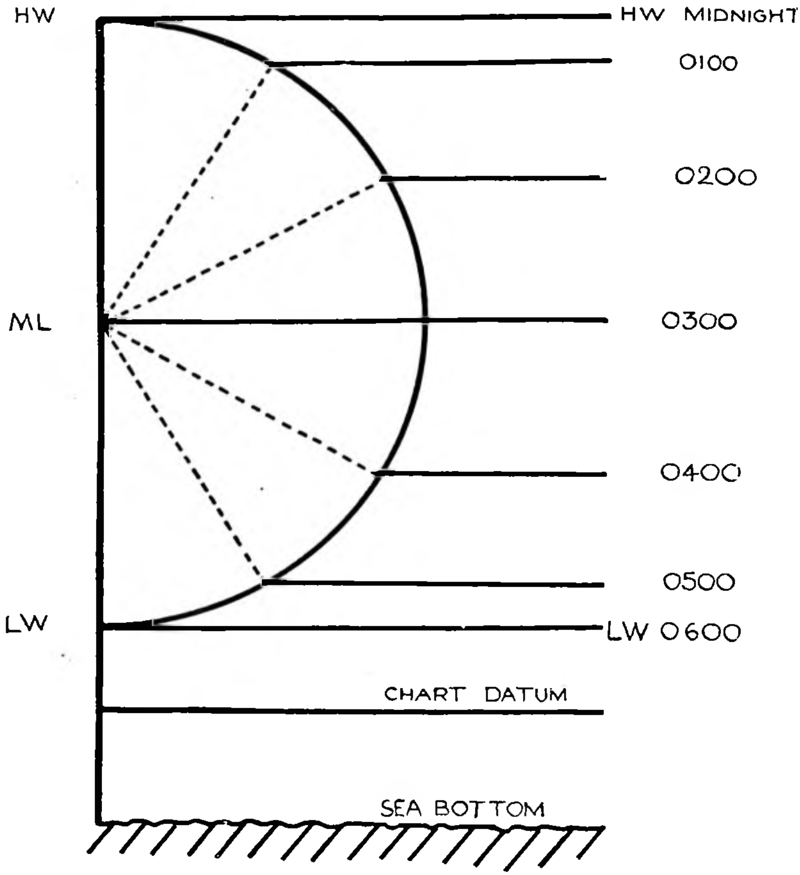
Examples for Practice No. 3.

Required the appropriate times of high and low water and state whether a rising or falling tide?

1. January 7 at 22 hr. 00 min. standard time off Devonport.
2. January 4 at 01 hr. 00 min. standard time off Devonport.
3. May 20 at 21 hr. 00 min. standard time off Dover.
4. May 27 at 00 hr. 00 min (midnight) standard time off Dover.
5. January 11 at 23 hr. 00 min. standard time off Devonport.

THE TIDAL DIAGRAM.

32. Let us examine a tide which is H.W. at midnight and L.W. at 0600. (See diagram.)



Now in each hour the tide has to cover an equal arc of the semicircle. (Imagine that a weight is slowly sliding down the semicircle and that it must cover an equal distance round the arc in a given time.) Now between midnight and 01 hr. 00 min. the level

of the tide moves over one-sixth of the arc of the semicircle (x). As the arc of the semicircle has only a gentle gradient to the horizontal the level of the water falls only a small amount.

During the next hour, 01 hr. 00 min. to 02 hr. 00 min., the tide moves through a further arc (x), but the gradient between the arc and the horizontal is much steeper now and the level of the water falls more quickly. Next the tide is moving through the arc x between 02 hr. 00 min. and 03 hr. 00 min. As this arc is practically vertical the level of the water is falling nearly as quickly as the tide's movement round the semicircle. We are now at 03 hr. 00 min. The level of the water is exactly half way between high and low water and falling at its quickest. This is because the arc of the semicircle is vertical and the movement of the tide round the arc is equal to the falling level of the water. It is now "half tide" and the height of the tide at this time is an important function known as mean level.

During the interval between 03 hr. 00 min. and 04 hr. 00 min. the tide continues to fall quickly; in fact, it falls the same amount as between 02 hr. and 03 hr.; but the rate of fall of the water level is gradually slowing up. Between 04 hr. 00 min. and 05 hr. 00 min. the fall in water level is much less and still slowing up.

In the last hour the water level falls very little and very slowly until at 06 hr. 00 min. it becomes low water which is, of course, the lowest level to which the water will fall.

From this we know that water level changes slowly near the times of high and low water but changes quickly at mean level or half tide.

If all tides took exactly six hours to rise or fall it would be comparatively simple to deduce a rule for the rise or fall in the tide for each hour from high or low water.

The "inch per foot" rule is a good example of this and gives surprisingly accurate results for ordinary tides of about six hours.

Rule.—The tide falls 1 inch per foot of range in the first hour after high water.

Two inches per foot of range in the next hour.

Three inches per foot of range in the next hour.

Then, of course, 3 inches, 2 inches and 1 inch per foot during the next three hours respectively as rate of the tide falling is now up.

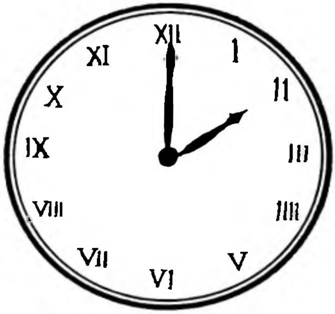
Supposing, for example, the range of tide between high and low

water is 10 feet. Then in the first hour the tide falls 10 inches (1 inch per foot). In the next hour it falls a *further* 20 inches (2 inches per foot). In the next hour it falls a *further* 30 inches (3 inches per foot), etc.

This rule is, of course, only to be used where the tide takes about six hours to rise or fall.

If the range had been 15 feet (a common range of tide in the British Isles) the rate of fall would have been 15 inches, 30 inches and 45 inches, *i.e.* 1 inch per foot of range during the first three hours, then 45 inches, 30 inches and 15 inches for the next three hours.

33. Thus we may liken the movement of the tide to the movement of the hour hand of a clock, remembering, of course, that while the hour hand of a clock always takes six hours to move from top to bottom the tidal pointer may take anything from three to ten hours to do this.



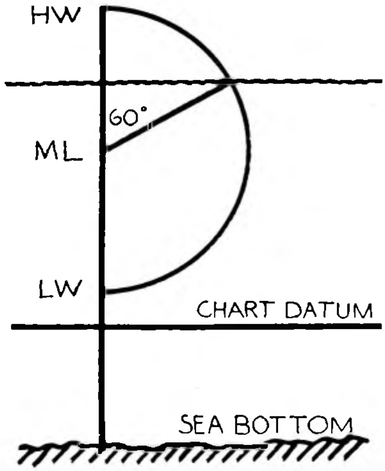
This movement is perfectly regular, however, and the angle it moves through is directly proportionate to 180° as the interval from high water is to the duration of fall. This angle is known as θ (theta), *e.g.* the duration of fall of tide is six hours and the interval from high water is two hours. Show the position of the tide on the tidal diagram.

Now $\frac{\theta}{180} = \frac{2 \text{ hr.}}{6 \text{ hr.}}$ (cross multiply to clear fractions)

$$\theta \times 6 = 2 \times 180$$

$$\therefore \quad \theta = \frac{2 \times 180}{6}$$

$$\theta = 60^\circ$$



In practice this angle θ is taken from a supplementary table in the *Tide Tables*; see A.T.T. I. Table 1a, but beginners should calculate it also until the principle is understood. Thence there is no point in calculating θ with a ready-made table at hand which is meant to be used.

Another Example.

What is θ when the interval from H.W. is 1 hr. 40 min. and the duration of fall 6 hr. 10 min.?

$$\frac{\theta}{180} = \frac{100 \text{ min.}}{370 \text{ min.}} \quad \text{(cross multiply)}$$

$$\theta \times 370 = 100 \times 180$$

$$\therefore \theta = \frac{100 \times 180}{370}$$

$$\theta = 49^\circ$$

It is more convenient to use minutes rather than hours and decimals of an hour in most cases for finding θ.

When the tide is nearer L.W. than H.W. the value of θ would be greater than 90°, and as this would involve a knowledge of second quadrant trigonometry we avoid this by always calculating θ from the nearest time of high or low water and applying any correction this gives to the appropriate tide.

Example.

Time of H.W. is at 06 hr. 00 min.; time of L.W is at 13 hr. 00 min. time of cast is 11 hr. 40 min. Required θ.

Here the interval from low water (1 hr. 20 min.) is the proper one to use to calculate θ as the cast is taken nearer L.W.

$$\text{now} \quad \frac{\theta}{180} = \frac{80}{420}$$

$$\theta \times 420 = 80 \times 180$$

$$\therefore \theta = \frac{80 \times 180}{420}$$

$$\theta = 34^\circ \text{ from L.W.}$$

Examples for Practice No. 4.

Required the value of θ, using the Supplementary Table 1a; also by calculation.

	Time of H.W.	Time of L.W.	Time of Cast.
1.	01h 00m	07h 00m	02h 00m
2.	01 00	07 00	05 00
3.	09 10	02 00	03 10
4.	16 05	10 00	15 00
5	17 12	23 18	20 15
6.	10 00	16 15	12 18

We will now proceed to complete the solution of the tidal diagram.

DATA.—

Time of cast	Time of H.W.	12h 00m	Ht. of H.W.	16·0 ft.
09h 50m	Time of L.W.	05 50	Ht. of L.W.	2·0
Duration of rise		06 10	Range	14·0

Nearest Tide

Time of H.W.	12h 00m	$\frac{\theta}{180°} = \frac{130}{370}$
Time of cast	09 50	$\therefore \theta = 63°$
		or Table 1a gives θ 63°
Interval from H.W.	2 10	

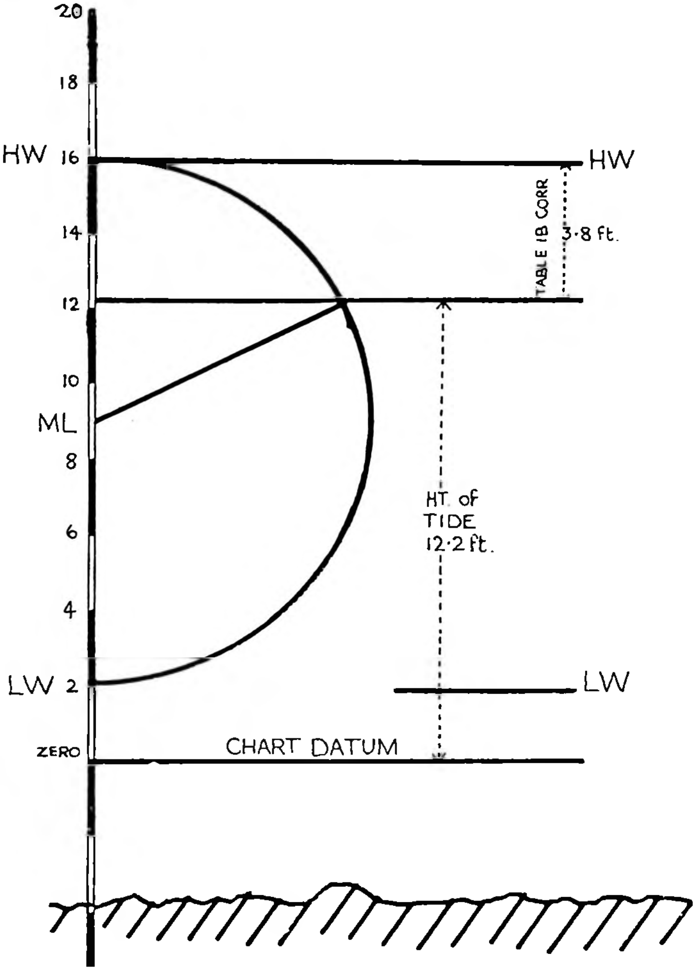
Draw the horizontal line chart datum.

Erect a vertical line, the tide pole; subdivide to feet.

Mark off the position of low and high water, 2 ft. and 16 ft. respectively. Fix the mean level. This is exactly half way between high and low water. It may be found either by trial and error or by calculation (H.W.+L.W.÷2 gives it position *above datum*).

Now draw the tidal semicircle centring your compasses at the M.L. and sweeping through H.W. and L.W. (not chart datum).

Now set off θ 63° from the M.L. (upwards as we are nearer high water than low water) until the tidal semicircle is reached. Through this point draw a horizontal line. This is the level of the tide at the required time and can be read off the tide pole as 12·2 ft. This result is confirmed by entering Table 1b with θ 63°, and range 14 ft. gives correction to H.W. 3·8 ft.



SCALE ¼" = 1 foot

∴ Ht. of H.W.	16·0 ft.
Correction —	3·8
Ht. of tide	12·2

SUMMARY OF RULES FOR THE WORKING OF PART I. (STANDARD PORT) PREDICTIONS.

1. Look up in the index for the number of page.

2. Bring the time of cast to standard time, quoted at foot of predictions.

3. Choose carefully the first time of tide that occurs *before* the standard time of cast and the first time of tide after the cast, being careful to note that one tide is a low water and the other a high water, it being immaterial which occurs first.

4. The difference in the times of high and low water is the duration of tide.

5. The difference in the heights of high and low water is the range of tide.

It should be noted that when the low water is below chart datum (marked by asterisk*) the range equals the sum of the heights of the tides.

6. The difference between the standard time of cast and the nearer time of high or low water is the interval from high (or low) water, as the case may be.

It occasionally happens that by a mistake the further time of tide is chosen instead of the nearer. This is easily seen when finding θ as in using Table 1a A.T.T. I a blank will be found, or if finding θ by calculation it will exceed 90°.

7. The angle θ is now found from Table 1a or by calculation. (See Worked Examples.)

8. With θ and the range of tide enter Table 1b, which gives the amount the tide is below high water or above low water according to which tide θ is calculated from.

This amount properly applied gives the required height of tide. This is the depth (or rise) of water above chart datum (or in rare cases the depth of water below chart datum) at the standard time of cast. When the height of tide is above chart datum, which is usually the case, it is the amount to *subtract* from the cast of the lead line to reduce it to chart datum. The corrected cast can then be looked for on the chart and the ship's position estimated.

Worked Example 1.

January 4 at 06 hr. 10 min. G.M.T. off DEVONPORT. Required the height of tide.

Time of H.W.	04h 01m	Ht. of H.W.	14·4 ft.
Time of L.W	10 17	Ht. of L.W.	2·0
Duration of fall	06 16	Range	12·4
Time of H.W.	04h 01m	Ht. of H.W.	14·4 ft.
Stand. time of cast	06 10	Corr. (Table 1b) —	3·3
Interval from H.W.	02 09	Ht. of tide	11·1

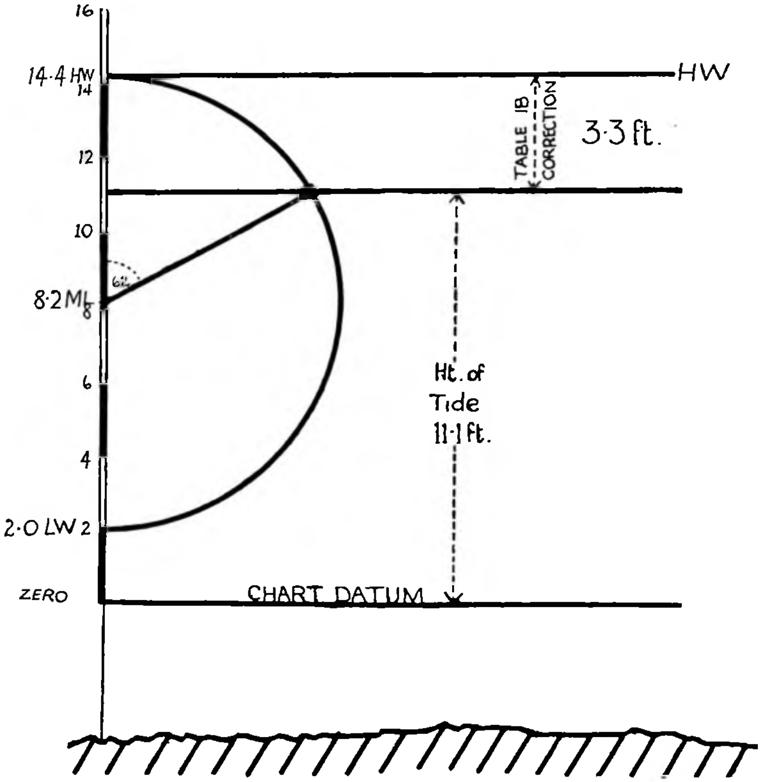
Table 1a $\theta = 62°$

NOTES.

1. The time of cast is G.M.T. which is standard time at Devonport.

2. The ship is on a falling tide being nearer H.W. than L.W.

3. The Supplementary Tables 1a and 1b solve accurately the tidal diagram opposite.


16
14·4 HW
14
12
10
8·2 ML
8
6
4
2·0 LW 2
ZERO
HW
TABLE IB
CORRECTION
3·3 ft.
62
Ht. of
Tide
11·1 ft.
CHART DATUM

Worked Example 2.

May 18 at 16 hr. 00 min. standard time off Dover. Required the correction to apply to the lead line to reduce the cast to the datum of the chart.

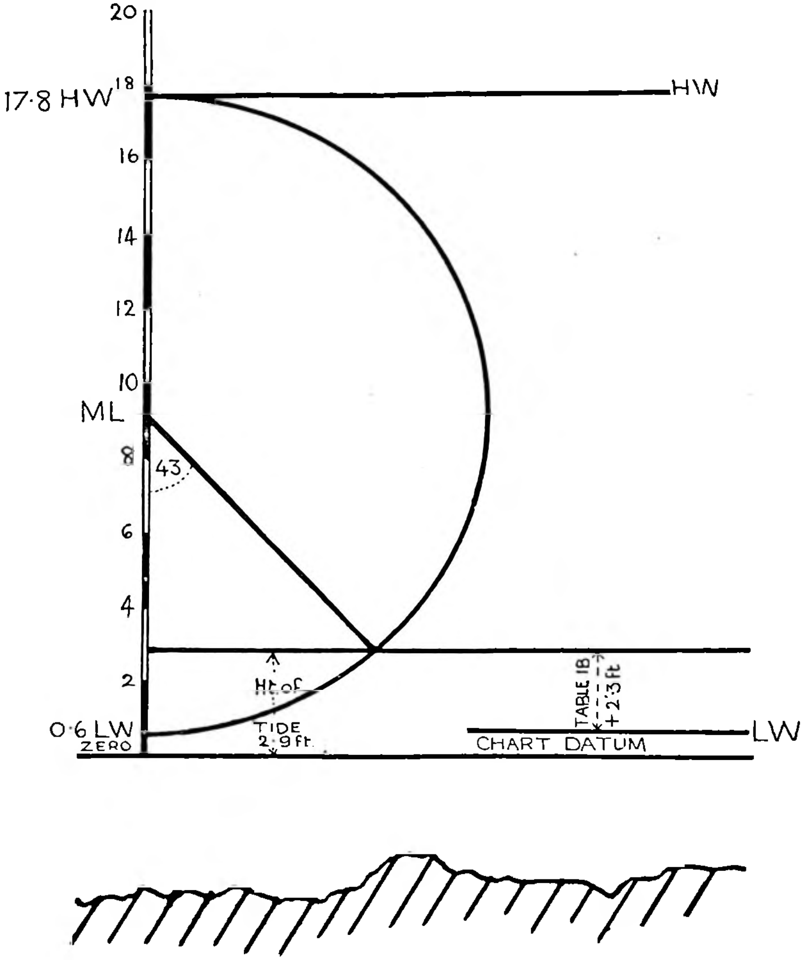
Time of H.W.	10h 30m	Ht. of H.W.	17·8 ft.
Time of L.W.	17 47	Ht. of L.W.	0·6
Duration of fall	07 17	Range	17·2
Time of L.W.	17h 47m	Ht. of L.W.	0·6 ft.
Stand. time of cast	16 00	Corr. (Table 1b)	+ 2·3
Interval from L.W.	01 47	Ht. of tide	2·9

Table 1a $\theta = 43°$

Correction to *subtract* from lead line 2·9 ft.

NOTES.

The correction from Table 1b is of course always additive when working from L.W.


20
17·8 HW 18
HW
16
14
12
10
ML
8
43
6
4
2
Ht of
TIDE
2·9 ft
TABLE IB
+2·3 ft
0·6 LW
ZERO
LW
CHART DATUM

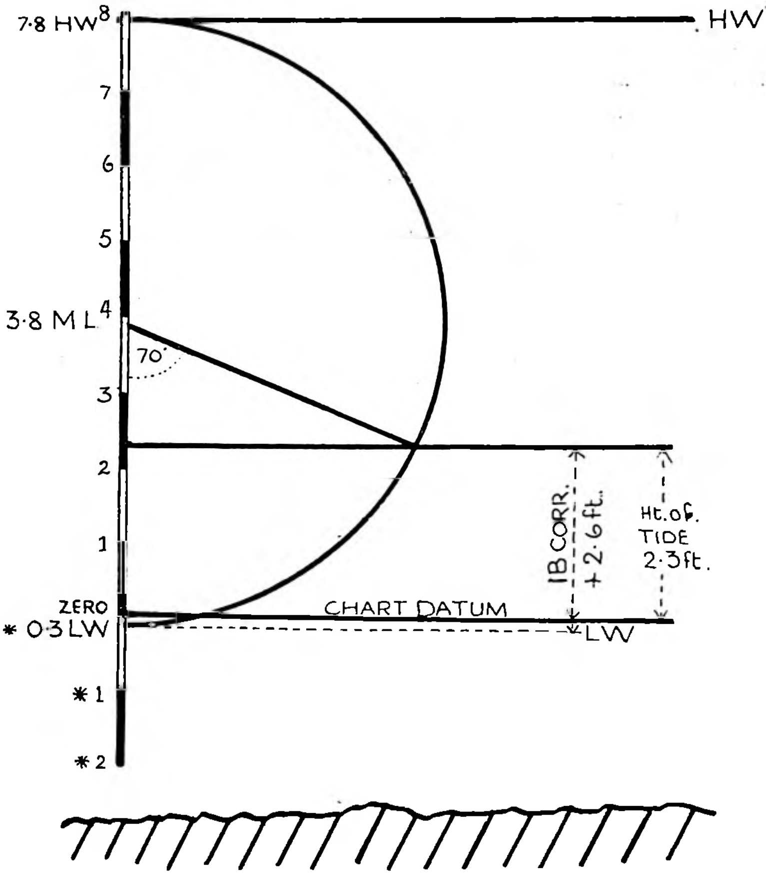
SCALE ¼" = 1ft.

Worked Example 3.

January 11 at noon L.M.T. off Helgoland. Required the height of tide.

Standard meridian	15° 00′ E.		
Long. Helgoland	7 54 E.		
Diff. of Long.	7 06 W = 28m		
Stand. time of cast	12h 28m		
Time of H.W.	16h 03m	Ht. of H.W.	7·8 ft.
Time of L.W.	10 12	Ht. of L.W.	* 0·3
Duration of rise	05 51	Range	8·1
Time of L.W.	10h 12m	Ht. of L.W.	* 0·3 ft.
Stand. time of cast	12 28	Corr. (Table 1b)	+ 2·6
Interval from L.W.	02 16	Ht. of tide	2·3

Table 1a $\theta = 70°$


7·8 HW
8
7
6
5
3·8 M L
4
70°
3
2
1
ZERO
* 0·3 LW
* 1
* 2
HW
IB CORR.
+ 2·6 ft.
Ht. of TIDE
2·3 ft.
CHART DATUM
LW

Worked Example 4.

March 5, 23 hr. 30 min. G.M.T. off Devonport. Required the height of tide.

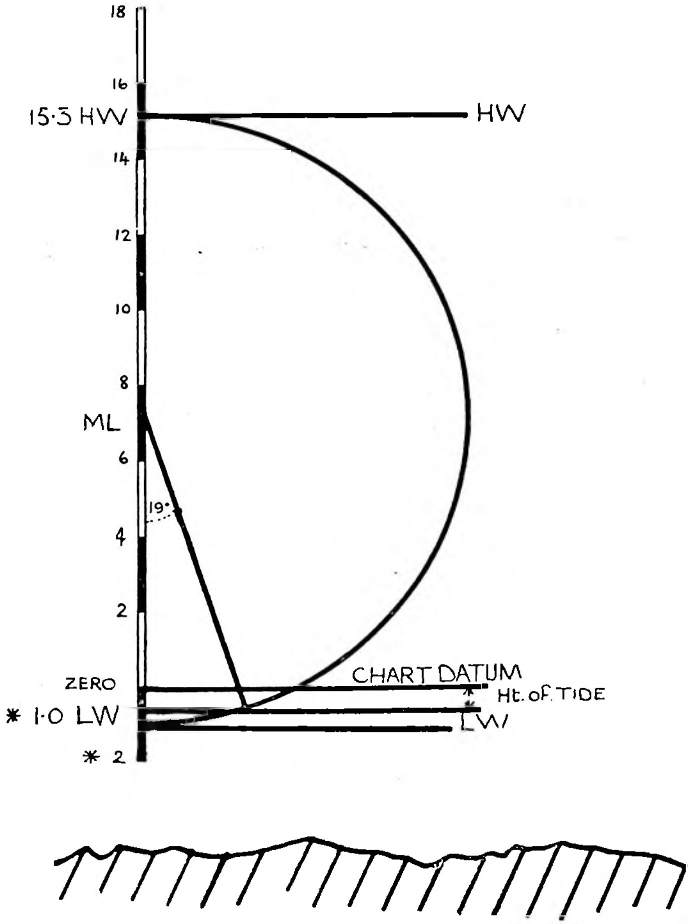
Time of H.W.	17h 49m	(Mar. 5) Ht. of H.W.	15·3 ft.
Time of L.W.	00 09	(Mar. 6) Ht. of L.W.	* 1·0
Duration of fall	06 20	Range	16·3
Time of L.W.	24h 09m	(Mar. 5) Ht. of L.W.	* 1·0 ft.
Stand. time of cast	23 30	(Mar. 5) Corr. (Table 1b)	+0·5
Interval from L.W.	00 39	Ht. of tide	* 0·5

Table 1a $\theta = 19°$

Notes.

The asterisk (*) before the height of L.W. denotes that on this day the water actually fell below the chart datum by 1 foot. That is, if a ship took a cast of the lead at or near L.W. the depth recorded would be less than the amount given on the chart. Thus, at the above time of cast, there would be half a foot to add to the cast of the lead line to correct it to chart datum.

For convenience of subtraction the time of L.W. on March 6 has been converted to March 5 by adding 24 hr.

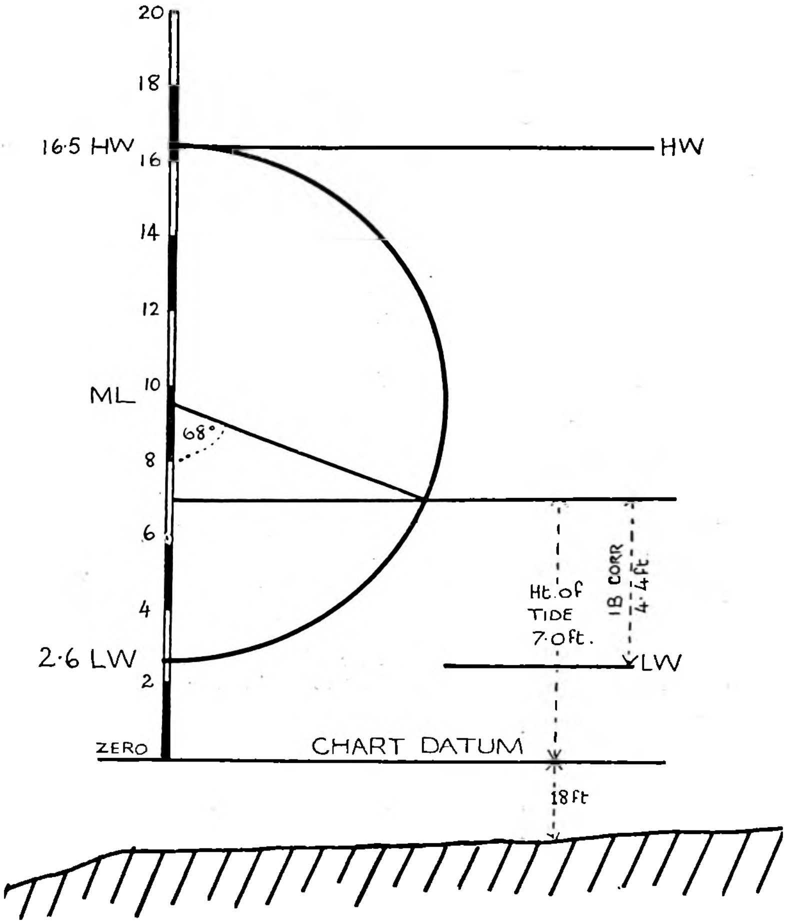

18
16
15·3 HW
HW
14
12
10
8
ML
6
19°
4
2
ZERO
CHART DATUM
Ht. of TIDE
* 1·0 LW
LW
* 2

Worked Example 5.

Required the amount of water over a 3-fm. patch off DOVER on June 25 at 15 hr. 15 min. B.S.T

Standard time of cast is 14 hr. 15 min.

Time of H.W.	17h 33m	Ht. of H.W.		16·5 ft.
Time of L.W.	12 14	Ht. of L.W.		2·6
Duration of rise	05 19	Range		13·9
Time of L.W.	12h 14m	Ht. of L.W.		2·6 ft.
Stand. time of cast	14 15	Corr. (Table 1b)	+	4·4
Interval from L.W	02 01	Ht. of tide		7·0
$\theta = 68°$		Depth of water at chart datum		18·0
		Depth of water over patch at 15 hr. 15 min. B.S.T.		25·0


20
18
16·5 HW
16
HW
14
12
ML
10
68°
8
6
Ht. of
TIDE
7·0 ft.
IB CORR
4·4 ft
4
2·6 LW
LW
2
ZERO
CHART DATUM
18 ft

SCALE · 1" = 4 ft.

Worked Example No. 6.

January 3 at noon L.M.T. off KEM?

Required (*a*) the depth of water above a rock marked "dries 1 ft."; (*b*) the ht. of Kem Lt.H. (50 ft.) above sea level at the above time.

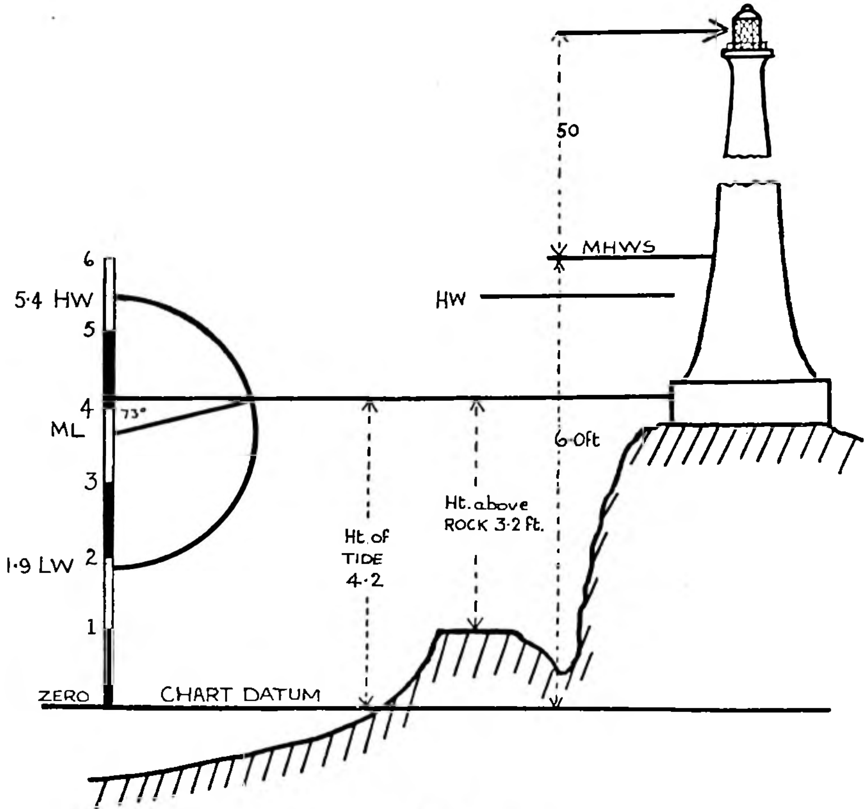
NOTE.—M.H.W.S. at Kem 6 ft. 0 in.

Long of standard meridian	30°	00′	E.
Long. of Kem	34	47	E.
Diff. of Long.	4	47	E. =19 m.

Standard Time 1141

Time of H.W.	13h	53m	Ht. of H.W.	5·4 ft.
Time of L.W.	08	28	Ht. of L.W.	1·9
Duration of rise	05	25	Range	3·5
Time of H.W.	13h	53m	Ht. of H.W.	5·4 ft.
Stand. time of cast	11	41	Corr. (Table 1b)	1·2
Interval from H.W.	02	12	Ht. of tide	4·2
$\theta = 73°$			Ht. above Rock 3·2 ft.	

Height of Lt.H. above M.H.W.S.	50·0 ft.
M.H.W.S.	6·0
Height of Lt.H. above chart datum	56·0
Height of tide	4·2
Height of Lt.H. above present sea level	51·8


50
MHWS
6
5·4 HW
5
4
ML
73°
3
2
1·9 LW
1
ZERO
HW
6·0ft
Ht. above
ROCK 3·2 ft.
Ht. of
TIDE
4·2
CHART DATUM

SCALE 1" = 2 ft.

D

Worked Example No. 7.

April 30 at 11 hr. 10 min. G.M.T. off HOEK VAN HOLLAND, Standard time 11 hr. 30 min. Required height of tide.

As the cast is taken within 20 min. of H.W., the height of the tide must be the height of H.W.—which is, time of H.W. 11 hr. 42 min.; height of H.W. 6·9 ft. Therefore required height of tide=6·9 ft.

NOTE.—It is practically impossible to interpolate a tide within 20 minutes of high or low water, and certainly in trying to do so you will not impress the examiner on your ability at tidal work.

Where tides are small and regular even a 30-minutes interval from high or low water is sufficiently accurate.

Worked Example No. 8.

Required the height of tide at LEE-ON-SOLENT at 17 hr. 56 min. G.M.T. January 27?

Lee-on-Solent is inside the Isle of Wight and we will choose Portsmouth as the Standard port.

At Portsmouth.

Time of H.W.	15h 12m	Ht. of H.W.	11·5 ft.
Time of L.W.	20 19	Ht. of L.W.	2·2
Duration of fall	05 07	Range	9·3
Time of L.W.	20h 19m	Factor	× ·25 ft.
Time of cast	17 56	Table 2b	
			+ 2·3
Interval before L.W.	02h 23m	Corrected M.L. at	
Corr. (Table 2a)	+ 00 04	Portsmouth	6·9 ft.
Corrected interval	02 27	Ht. of tide at Lee-on-Solent	9·2

NOTES.

Lee-on-Solent is inside the Isle of Wight and a special correction to Portsmouth or Southampton in necessary. Choose Ports-

mouth, say, as the Standard port. Take the interval from L.W. (always) and apply small correction to this from Table 2a given below.

Now multiply the range of tide at Portsmouth by factor from Table 2b. Apply this to mean level at Portsmouth. This gives the height of tide at Lee-on-Solent.

The mean level is, of course, found by adding height of high and low water together and dividing by two.

There is no correction to the M.L. at Portsmouth at Lee-on-Solent. (See bottom of Table 2b.)

TABLE II. Height of Tide at Places inside the Isle of Wight.

(*a*) Correction to Interval

Interval from L.W. Portsmouth	Duration of Fall				
	Corr. +			Corr. −	
	h $4\frac{3}{4}$	h 5	h $5\frac{1}{4}$	h $5\frac{1}{2}$	h $5\frac{3}{4}$
h	m	m	m	m	m
02	12	06	00	06	10
$\frac{1}{4}$	14	07	00	06	12
$\frac{1}{2}$	15	08	00	07	13
$\frac{3}{4}$	17	08	00	08	14
03	19	09	00	08	15

(*b*) Factors
PORTSMOUTH

Corrected Interval	Lee-on-Solent Factor
h m	
02 45 before	+ 0·31
30	+ 0·26
15	+ 0·19
00	+ 0·12
Correction to M.L.	Ft. 0·0

Examples for Practice No. 5.

Question 1.—May 25 at 04 hr. 20 min. standard time off DOVER. Required the correction to apply to the lead line before comparing with the depths on the chart.

Question 2.—February 4 at 16 hr. 40 min. standard time off PORTSMOUTH. Required the height of the tide.

Question 3.—April 9 at 04 hr. 55 min. P.M. standard time off DEVONPORT. Required the correction to apply to the lead line before comparing with the depths on the chart.

Question 4.—April 14 at 04 hr. 26 min. standard time off DEVONPORT. Required the height of the tide.

Question 5.—June 8 at 20 hr. 12 min. B.S.T. off LONDON BRIDGE. Required the height of the tide.

Question 6.—February 11 at 03 hr. 54 min. zone time (Zone — 1) off HELGOLAND. Required the correction to apply to the lead line before comparing with the depths on chart.

Question 7.—January 6 at 01 hr. 27 min. local mean time off HELGOLAND. Required the correction to apply to the lead line before comparing with depths on chart.

Question 8.—May 22 at 22 hr. 40 min. local mean time off DOVER. Required the total depth over a rock marked 2 fathoms on the chart.

Question 9.—July 23 at 12 hr. 08 min. local mean time off DOVER. Required the height of tide.

Question 10.—November 29 at 04 hr. 15 min. local mean time off PORT OF BRISTOL (King Road), took a cast of the lead. Required the correction to apply to the lead line before comparing with depths on chart.

Question 11.—April 23 at 16 hr. 10 min. local mean time off HOEK VAN HOLLAND. Required the total depth over a wreck marked 4 fathoms on the chart.

Question 12.—June 21 at 09 hr. 43 min. standard time off DUNGENESS. What would you enter with in the tide tables on the chart in order to determine the direction and rate of the tidal stream?

Question 13.—March 6 at 01 hr. 20 min. standard time off DEVONPORT. Required the depth there would be over a rock marked 4 fathoms on the chart.

Question 14.—July 6 at 16 hr. 50 min. standard time off LONDON BRIDGE. Required the height of the tide.

Question 15.—March 2 off HELGOLAND at 16 hr. 53 min. took a cast of the lead then at 15 minute intervals. Reduce the casts to chart datum. (Casts in order gave 44 ft., 48 ft., 51 ft., 56 ft., 61 ft.)

Question 16.—September 7 at 07 hr. 59 min. zone time (zone + 1) off SIERRA LEONE (Freetown). Required the total depth at a wharf where the chart indicates 2½ fathoms.

Question 17.—February 10 at 17 hr. 46 min. standard time off HELGOLAND. What would the height above sea level be of a lighthouse stated on chart as 160 ft.? (Mean high water springs 8·5 ft.)

Question 18.—May 6 at 23 hr. 50 min. standard time off LONDON BRIDGE there was a depth of 40 ft. at a jetty. Required the depth at the following low water.

Question 19.—November 20 at 02 hr. 16 min. standard time off PORT OF BRISTOL (King Road). What depth should a ship anchor in so that at low water she will have 10 ft. beneath her keel? (Ship's draught 26 ft.)

Question 20.—Pick out the times and heights of high and low water in the morning of June 20 at DOVER.

TO FIND THE TIME AT WHICH A GIVEN HEIGHT OF TIDE MAY BE EXPECTED.

Worked Example 1.

Off Devonport. What is the earliest standard time in the morning of January 7 when the height of tide will be 15 ft.?

Time of H.W.	06h 38m	Ht. of H.W.	17·1 ft.
Time of L.W.	00 33	Ht. of L.W.	0·5
Duration of rise	06 05	Range	16·6

Nearest tide, height of H.W.	17·1 ft.
Required height of tide	15·0
Required height of tide is below H.W.	2·1

Table 1b. Range 16·6 ft. and correction 2·1 ft. gives θ 42°.

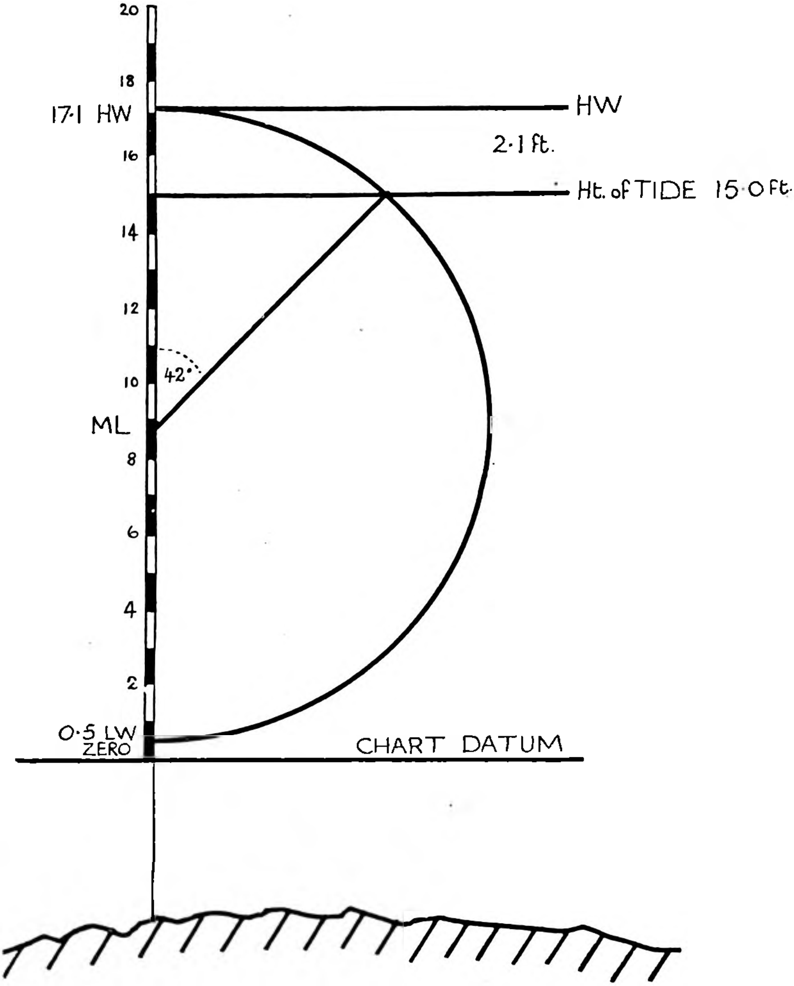
Table 1a. Duration of rise 06 hr. 05 min. and θ 42° gives interval from H.W. 1 hr. 25 min.

Time of H.W.	06h 38m	
Interval before H.W.	01 25	
Standard time	05 13	when height of tide will be 15 ft.

Notes.

The first tide of the day is a low water shortly after midnight at 00 hr. 33 min., height 0·5 ft. The following high water is at 06 hr. 38 min. As the required height of tide is 15 ft.—only 2·1 ft. less than high water—it is clear that the required time will be found nearer high water than L.W. Having chosen the tide, 00 hr. 33 min. to 06 hr. 38 min., we take the difference between the height of the nearest tide, H.W. 17·1 ft. and the required height of tide 15·0 ft.; this is 2·1 ft.

We now enter Table 1b with the range 16·6 ft. noting the angle that corresponds with the correction 2·1. In this case 42° is a good approximation. Enter Table 1a with θ 42° and duration 06 hr. 05 min. and the required interval is about half-way between 01 hr. 20 min. and 01 hr. 30 min. Take 01 hr. 25 min. as a solution. Now apply this interval to the time of H.W. towards the time of L.W.


20
18
17·1 HW
HW
2·1 ft.
16
Ht. of TIDE 15·0 ft.
14
12
42°
10
ML
8
6
4
2
0·5 LW
ZERO
CHART DATUM

Worked Example 2.

At what time in the early afternoon of March 14 will the height of tide be 6·0 ft. off PORTSMOUTH?

Time of high water	18h 43m	Height of high water	9·7 ft.
Time of low water	11 07	Ht. of low water	4·1
Duration of rise	07 36	Range	5·6

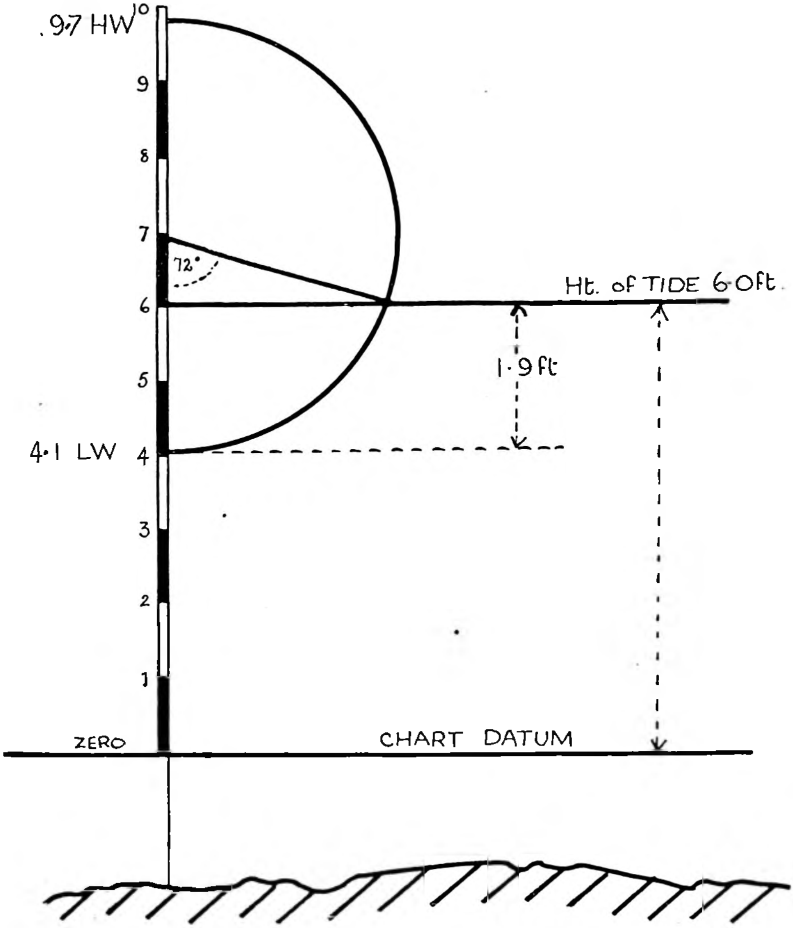
Height of low water	4·1 ft.
Required height of tide	6·0
Required height of tide is above low water	1·9

Table 1b.

Range 5·6 ft. and correction 1·9 ft. gives θ 72°

Table 1a: with θ 72° and duration of rise 07 hr. 36 min. gives interval from low water as 3 hr. 3 min.

Time of low water	11h 07m	
Interval from L.W.	03 03	
Standard time	14 10	when there will be height of tide of 6 ft. 0 ins.


9·7 HW
10
9
8
7
72°
Ht. of TIDE 6·0ft.
6
1·9 ft
5
4·1 LW
4
3
2
1
ZERO
CHART DATUM

Worked Example 3.

At what standard time in the evening of February 6 off KING ROAD, Port of Bristol, will it be safe to pass over a shoal marked 4 fms.? The ship's draft is 25 ft., a safe clearance of 10 ft. being required.

The total depth of water required over the sea bottom is 35 ft. The depth of water over the shoal at chart datum is 24 ft. (4 fathoms), Therefore the required height of tide is 11 ft. Thus we require 11 ft. more water than there is at datum.

Time of H.W.	21h 04m	Ht. of H.W.	45·0 ft
Time of L.W.	15 57	Ht. of L.W	* 1·0
Duration of rise	05 07	Range	46·0

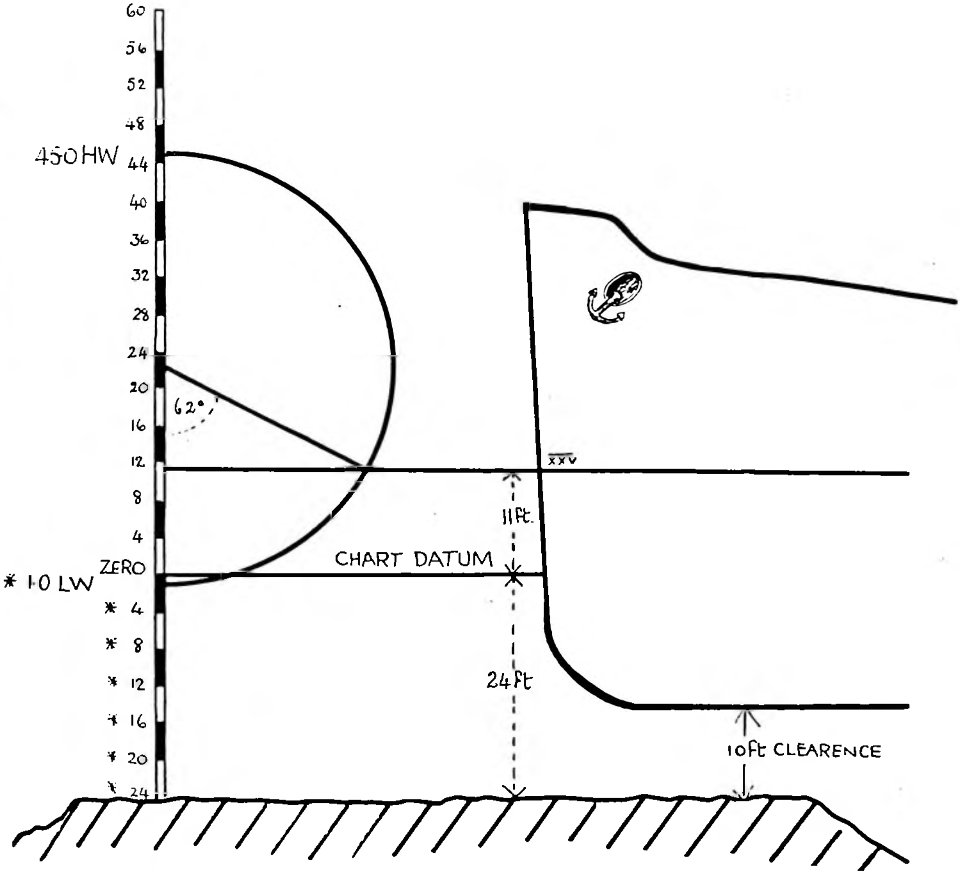
Height of L.W.	* 1·0 ft.
Required height of tide	11·0
Required height of tide is above L.W.	12·0

With range 46·0 ft., cor. 12·0 Table 1b gives $\theta = 62°$

Table 1a $\theta = 62°$ and duration of rise 05 hr. 07 min. gives interval from L.W. as 01 hr. 47 min.

Time of L.W.	15h 57m	
Interval from L.W.	01 47	
Standard time	17 44	when there will be 11·0 ft. height of tide.

NOTES.—Table 1b gives range up to 20 ft. only. Hence we must enter Table 1b with one-third values, *i.e.* 4·0 ft. and 15·3 ft. (It is a nuisance this, but there is nothing better to be done. With tremendous ranges like 46·0 ft. unless we draw a diagram the size of a blackboard we shouldn't get near the above result even.)


60
56
52
48
450 HW 44
40
36
32
28
24
20
62°
16
12
XXV
8
11 ft.
4
ZERO
CHART DATUM
* 1·0 LW
* 4
* 8
* 12
24 ft
* 16
10 ft CLEARENCE
* 20
* 24

TO FIND TIME.

Examples for Practice No. 6.

Question 1.—January 4 off DEVONPORT. Required the standard time when there would be a height of tide of 12 ft. in the evening on a falling tide.

Question 2.—Off DOVER in the morning of May 22. At what standard time would there be a height of tide of 2 ft. on a falling tide?

Question 3.—February 12 off HELGOLAND, in the early afternoon. Required the standard time there would be a total depth of 30 ft. over a patch marked 4 fathoms on the chart.

Question 4.—On the morning of April 10 off HELGOLAND, tide falling. At what local mean time would there be a depth of 20 ft. off a wharf where the chart showed 3 fathoms?

Question 5.—March 8 off DEVONPORT during the forenoon watch. At what local mean time would there be enough water for a ship drawing 20 ft. to cross a patch marked 3 fathoms so as to give a clearance of 10 ft. beneath the keel?

Question 6.—June 22 off DOVER in the morning. How long will it take the tide to rise 2 ft. above low water?

Question 7.—In the afternoon watch on January 6 off HELGOLAND. How long will it take the tide to fall 3 ft. from high water?

Question 8.—About noon on February 4 off DEVONPORT. How long would it take the tide to rise a foot above low water?

Question 9.—What would be the latest time a ship could leave DOVER on the morning of May 21 where chart indicated 3 fathoms so as to have a 5 ft. clearance. (Ship's draught 20 ft.)

Question 10.—January 7 off DEVONPORT. A rock is marked (dries 5 ft.); at what time will it be awash during the early morning?

Question 11.—Until what time in the afternoon of February 12 off DEVONPORT will there be 25 ft. of water above a shoal marked 3 fathoms?

Question 12.—September 14, at 10 hr. standard time, a vessel grounded on a sandbank off Sierra Leone. After pumping out fuel oil her mean draft was expected to be reduced 2 ft. At what standard time will she be expected to float on the next tide?

ADMIRALTY TIDE TABLES, PART II. (A.T.T. II.).

48. This volume contains more than 8000 positions, arranged geographically. The positions are consecutively numbered, and the index at the end of the book gives the number of the position——and *not* the number of the page. Each area is headed by a notice that gives its standard time meridian and the correction to apply to that standard time to get G.M.T. (par. 28).

49. To the right of the name of the position is given its latitude and longitude. Then follow the harmonic constants of the four principal constituents, the value of M_o or Z_o; the difference in time between the time of high water at a specified Standard port and the time of high water at that position; and a ratio that indicates the amount of the range of the tide at that position as compared with the range of tide at the specified Standard port.

50. With regard to the time difference, we must note that the sign (+ or —) indicates how it is to be applied to times of high and low water at the Standard port. It is the average value of the difference and can be applied to both high and low water times. If the difference at low water is 20 minutes or more different from the high water difference we are given two time differences; the upper one is the high water difference, and the other one applies to the low water.

51. With regard to the ratio, we must note that this is always the ratio of the range, and if we multiply the range at the Standard port by the quanitity given we shall get the range at that position. We can also use it as a ratio of rises in cases where there is *no R in the "Reference" column.*

52. To the left of the name of the position we have a very important column containing letters and symbols. Some of these are interpreted at the bottom of the page, and all of them are explained on pp. vii and viii. They are as follows:—

- R The ratio is to be used for the range only, not the rise (par. 51).
- U The values given cannot be relied on completely.
- * A shallow water correction must be taken from p. 112.
- † Seasonal corrections from p. 112 must be applied.
- ‡ The values of "H" are given to two places of decimals.

a The constants have been computed by the Admiralty method.

i Constants are inferred, and not found by actual observation.

t Z_0 is given as M_0, or M_0 is given as Z_0.

x Z_0 or M_0 are inferred values.

The last four are of no importance whatever to seamen.

53. The following extracts from A.T.T. II. will illustrate the preceding paragraphs.

No.	Reference	Place	Position Lat.	Position Long.	Harmonic Constants M^2 G	M^2 H	S^2 G	S^2 H	K^1 G	K^1 H	O^1 G	O^1 H	M_0	Time Difference H M	Ratio
15	R*ix	Cargreen	50° 26′ N.	4° 12′ W.	116°	4·4′	219°	1·7′	115°	0·3′	334°	0·2	8·2	+0015	0·8
4034	U†*t	Basra	30° 30′ N.	47° 53′ E.	101°	1·3′	170°	0·4′	030°	0·8′	355°	0·5′	5·1	+0538 +0641	0·55

54. At the end of the list of positions we have the Supplementary Tables. Table 1 is a list of positions having shallow water corrections; and gives the time and height quantities to be applied, according to the prefixed sign, to the H.W. and L.W. times and heights. Table 2 is a list of positions at which the value of A_0, M_0, or Z_0 varies during the year. It tabulates the height constants to be applied, according to the prefixed sign, in each month of the year. Table 3 concerns the prediction of currents. Table 4 is an astronomical table of the time of the Moon's first transit on each day of the years 1938 to 1942, and the Moon's horizontal parallax at noon of every day in these years.

70. Our final remark on tide prediction is that the student must remember that his result will only be an approximate time and an approximate height. Rigid accuracy can only be obtained by using at least twenty of the harmonic constants, and even then meteorological conditions can cause large divergences. In spite of this, however, the predictions should be carefully and studiously computed with a view to getting an approximation that is as accurate as possible. It is a good exercise to calculate the time and height of high or low water at a port with officially predicted tides. If these predictions are worked out by non harmonic, harmonic and Admiralty methods it will be illuminating to compare the worked results with the official prediction. It might also be illuminating to compare the official prediction with the actual time and height of the tide!

ADMIRALTY TIDE TABLES, PART II.

Method of Finding the Height of Tide by Tidal Differences and Ratio of Ranges.

To Bring the Time of Cast up to Standard Time.

First look up the number of the port in question in the index at the *back* of A.T.T. II.

Supposing the question to be—

January 10 at 14 hr. 00 min. G.M.T. off Penzance.

In the index Penzance is found to be No. 2 and should be looked up in the Tide Tables in column 1, headed "No."

Above the data for Penzance is given—

Time Meridian: Greenwich
(S.T.: 0000)

This means standard time for Penzance is Greenwich mean time, and whether the case is given as standard time or G.M.T. there is no correction to be applied.

Suppose the problem was—

January 10 at 14 hr. 00 min. S.M.T. off Penzance.

Now S.M.T. or L.M.T. is local time at place and must be brought up to the standard meridian that the data for Penzance are made up from.

Long of stand. mer.	00° 00′
Long of Penzance	5 33 W.
Diff. of long.	5° 33′ W = 22 min.

"Standard time is best when ship is west."

Standard time will be 22 min. ahead of S.M.T. at Penzance.

Therefore standard time of cast is 14 hr. 22 min.

Suppose the problem to be—

January 10 at 14 hr. 00 min. B.S.T. off Penzance.

B.S.T. is British summer time which is, of course, one hour ahead of G.M.T. Therefore 14 hr. 00 min. B.S.T. equals 13 hr. 00 min. G.M.T., and as G.M.T. is standard time at Penzance the required standard time is 13 hr. 00 min.

Examples for Practice No. 7.

Required the standard time of cast in the following examples:

1. July	1 at	12h	00m	G.M.T., off Devonport.
2. Feb.	8 at	10	00	Stand. time off Penzance.
3. July	4 at	16	10	S.M.T. off Fowey.
4. July	4 at	16	10	L.M.T. off Dover.
5. May	12 at	00	30	B.S.T. off Penzance.

Where the Standard Meridian is not the Greenwich Meridian.

Example.—July 10 at 10 hr. 00 min. G.M.T. off Onega.

Above Onega is

Time meridian 30° E. (S.T.: − 0200)

This means that standard time is two hours ahead of G.M.T. Therefore standard time of cast is 12 hr. 00 min.

It would be much clearer if the equation was given fully in the Tide Tables, *i.e.*—

Time meridian 30° E. (S.T. − 0200 = G.M.T.)

By transposing simply we would have—

Time meridian 30° E. (S.T. = G.M.T. +0200)

Until the authorities give the full equation it will have to be remembered that S.T. − 0200 means standard time is 2 hours *ahead* of G.M.T., while S.T. + 0200 means that standard time is 2 hours behind G.M.T.

Actually an intelligent navigator must know that standard meridians in East Longitude are ahead of G.M.T.; while standard meridians in West Longitude are behind G.M.T.

Example.—

Jan. 11 at 11 hr. 10 min. L.M.T. off Onega.

Long stand. meridian	30° 00′ E.	
Long. Onega	38 01 E.	
Diff. long.	8 01 E.	= 32 min. E'ly.

"Standard time is least when ship is east."

Onega is east of the standard meridian and therefore local time at Onega is ahead of standard time by 32 minutes. Therefore standard time of cast is 10 hr. 38 min.

Examples for Practice No. 8.

Required standard time of cast.

1. Feb. 10 at 12h 30m G.M.T. off Wilhemshaven.
2. May 8 at 08 00 G.M.T. off Burntcoat Head.
3. Feb. 17 at 03 00 G.M.T. off Sandy Hook
4. Sept. 27 at 04 30 G.M.T. off Darwin.
5. July 19 at 12 00 L.M.T. off Wilhemshaven.
6. May 10 at 08 00 S.M.T. off Cape Palmas.

SECONDARY PORTS.

The Subsidiary Method of Finding Height of Tide, etc., for Ports which are not Standard Ports, using the Ratio of Ranges and Tidal Differences.

Worked Example 1.

May 25 at 12 hr. 00 min. G.M.T. off Dungeness.

(87) Dungeness. Reference *i. On Dover — 00hr. 15 min.; 1·2.

	High Water			Low Water		
Dover	15h	45m	16·9 ft.	10h	33m	1·6 ft.
Tidal difference and ratio	—00	15	× 1·2	—00	15	× 1·2
Dungeness	15	30	20·3	10	18	1·9

Time of H.W.	15h	30m	Height of H.W.	20·3 ft.
Time of L.W.	10	18	Height of L.W.	1·9
Duration of rise	5	12	Range	18·4
Time of L.W.	10h	18m	Height of L.W.	1·9 ft.
Stand. time of cast	12	00	Table 1b corr.	+ 4·4
Interval from L.W.	1	42	Height of tide	6·3

Table 1a $\theta = 59°$

Notes on Worked Example 1.

1. Look up the number of the port in the index to Part II. This gives Dungeness 87.

2. Look above Dungeness for the standard meridian. This is Greenwich. As the cast is given in G.M.T. there is no correction to make to it.

3. Look in the "Reference" column and see whether R is given. If it is, then the ratio of ranges method *must* be used (see Worked Example 3). If R is not contained in the Reference column then either the ratio of rises or the ratio of ranges method may be used. As the ratio of rises is a much simpler and more direct method this should be used when the reference does not contain R.

4. In the columns headed "Time Difference" and "Ratio" it will be seen that the Standard port for Dungeness is Dover and that the time difference is — 00 hr. 15 min. and that the ratio of rise is 1·2.

5. Choose a suitable high and low water at Dover from A.T.T., Part I. Apply the time difference to *both* times of high and low water at Dover; this gives, of course, the times of high and low water at Dungeness. Multiply the height of tide at Dover at high and low water by the ratio 1·2; this gives the heights of high and low water at Dungeness.

6. Now proceed as though Dungeness is a Standard port—to which we have virtually reduced it.

Worked Example 2.

January 6 at 00 hr. 30 min. G.M.T. off Norddeich haven. Required height of tide.

1446 * i Norddeich haven — 00 17 1·04 on Helgoland.
— 00 43

Time meridian is 15° E. (S.T. —01000) that is, standard time is one hour ahead of Greenwich. Therefore standard time of cast is 01 hr. 30 min.

	High Water		Low Water	
	h m	ft.	h m	ft.
Helgoland	23 28 (Jan. 5)	6·9	06 18 (Jan 6)	0·0
Tidal difference and ratio	—00 17	×1·04	—00 43	×1·04
Norddeich haven	23 11	9·2	05 35	0·0

	h m		ft.
Time of H.W.	23 11 (Jan. 5)	Height of H.W.	9·2
Time of L.W.	05 35 (Jan. 6)	Height of L.W.	0·0
Duration of fall	06 24	Range	9·2

	h m		ft.
Time of H.W.	23 11 (Jan. 6)	Height of H.W.	9·2
Stand. time of cast	01 30 (Jan. 5)	Corr. Table 1b	—2·7
Interval from H.W.	02 19	Height of tide	6·5

Table 1a gives $\theta = 66°$

Notes on Worked Example 2.

1. Number of port is 1446.

2. Standard meridian is 15° E. (S.T. —0100.)
   Therefore standard time is one hour ahead of G.M.T. Time of cast thus becomes 01 hr. 30 min. standard time.

3. There is no R in the Reference column so we will use the ratio of rises method as in Worked Example 1.

4. In the column "Time Difference" the Standard port for Norddeich haven is Helgoland. There are two time differences given
   —00hr 17m
   —00 43
   The first is the H.W. difference; the second is the L.W. difference (see par. 50). The ratio 1·04 is used as in Worked Example 1.

Worked Example 3.

April 14 at 15 hr. 10 min. standard time off Penzance. Required height of tide.

2 R* Penzance — 00 hr. 38 min.; 1·02 on Devonport.

R indicates that ratio (1·02) must be used as ratio of ranges We will first proceed to find the times of high and low water as usual.

Times.

	High Water.	Low Water.
Devonport	13h 47m	20h 08m
Tidal difference	—00 38	—00 38
Penzance	13 09	19 30

Heights.

	High Water.	Low Water
Devonport	11·6 ft.	4·6 ft.
M_0 at Devonport	8·2	8·2
"Half" range at Devonport	3·4	3·6
Penzance ratio	1·02	1·02
"Half" range at Penzance	3·5	3·7
M_0 at Penzance	9·7	9·7
Heights at Penzance	13·2	6·0

Time of high water	13h 09m	Height of high water	13·2 ft.
Time of low water	19 30	Height of low water	6·0
Duration of fall	6 21	Range	7·2
Time of high water	13h 09m	Height of high water	13·2 ft.
Stand. time of cast	15 10	Correction Table 1b	—1·6
Interval from H.W.	02 01	Height of tide	11·6

Table 1a gives 0 = 57°

Notes on Worked Example 3.

1. Number of port is 2.
2. Standard meridian for Penzance is Greenwich. The time of cast is given in standard time therefore no adjustment is required.
3. There is an R in the "Reference" column and although this does not affect the time difference which is applied as usual, the ratio of rises method cannot be used as in Worked Examples 1 and 2.

The method of using the ratio of ranges is first to find the half range at the Standard port for H.W. This is height of H.W minus M_o (mean tide level). Multiply the half range at Devonport by the ratio. This gives the half range at Penzance and applied to M_o (mean tide level) at Penzance we have the height of H.W

We now find the height of L.W. at Penzance similarly.

Height of L.W. (Devonport) $\sim M_o$ (at Devonport)
= half range at Devonport.

Half range at Devonport $\times$ ratio
= half range at Penzance

M_o (at Penzance) minus half range (at Penzance)
= Height of L.W. at Penzance.

We now have the times and heights of high and low water at Penzance and the problem proceeds on the usual lines.

Examples for Practice No. 9.

Required height of Tide.

1. May 25 at 04 hr. 00 min. G.M.T. off Dungeness.
2. January 6 at 16 hr. 00 min. G.M.T. off Norddeich haven.
3. January 4 at 12 hr. 10 min. G.M.T. off Penzance.
4. November 29 at 17 hr. 17 min. L.M.T. off Walton Bay.
5. March 5 at 23 hr. 00 min. standard time off Teignmouth.
6. March 6 at 04 hr. 10 min. G.M.T. off Lizard Head.
7. September 7 at 12 hr. 20 min. G.M.T. off Cape Palmas.
8. January 3 at 12 hr. 50 min. G.M.T. off Onega.
9. March 8 at 14 hr. 20 min. standard time off Fowey.
10. May 18 off Folkestone. What depth of water will there be over a rock (marked dries 1 ft.) at 10 hr. 50 min. G.M.T.?
11. April 15 off Penzance. Will it be safe to pass over a shoal (awash at M.L.W.S.) at 13 hr. 20 min. G.M.T.? The least depth of water required is 12 feet.
12. At what standard time about noon on April 14 will there be a depth of 20 ft. above a shoal charted 2 fathoms off Cargreen?

THE HARMONIC METHOD.

1. When we carefully look through the Tide Tables for a port, especially when in the Pacific or Indian Ocean, we are struck by the fact that the times and heights or tides can be, and often are, amazingly irregular. Sometimes the interval between two high waters may be as small as 8 hours and at other times it may be as much as 26 hours. In addition to this we can also notice that the heights of high water are definitely irregular. Here are the high waters at Hong Kong for one week:—3·9, 7·2, 4·2, 7·5, 4·5, 7·6, 4·7, 7·6, 5·0, 7·5 (feet).

2. Looking at the above figures we realise that there must be other factors acting on the tides besides those we have already studied. A careful observation of tidal times and heights shows that we can easily divide tides into three distinct and obvious classes. The first division contains the regular semidiurnal tides, with which we have already dealt. The second division contains tides that have one high water only on each day: these are termed "diurnal" tides. The third division contains tides that have features partly diurnal and partly semidiurnal: and these are termed "mixed" tides.

3. No tide is perfectly diurnal or perfectly semidiurnal; so all tides are really "mixed" tides. We therefore define diurnal tides as those in which the daily features are most prominent; semidiunral tides being those in which half daily features are most prominent, mixed tides are those in which neither the diurnal nor semidiurnal features are predominant. But we must remember that nearly all tides are marked by diurnal and semidiurnal characteristics.

4. When we consider the causes of the irregularity of tides we find that they may be due to various well-known forces. The Moon goes round the Earth in an elliptical orbit in a little less than four weeks ($27\frac{1}{3}$ days). When it is nearest the Earth (perigee) its distance is about $\frac{6}{7}$ of its distance when farthest away (apogee). As its gravitational attraction varies inversely as the square of its distance, we shall have a pull of 49 units when in perigee and a pull of 36 units when in apogee. This is approximately as 4 is to 3. Obviously this will have an effect on the tidal undulations produced.

5. The Moon goes from its maximum northerly declination to its maximum southerly declination in about four weeks. As it takes

its tidal undulation with it we are bound to find that, in any latitude, we shall get varying tidal effects with varying declinations of the Moon.

6. As the Sun also is a tide forming body we must expect changes in the tide due to changes in his declination. His change of distance is not so important as that of the Moon and can be considered negligible; but the changes in declination cannot be neglected. The main point, however, is that these changes are spread over a year in the case of the Sun, and not 27 days as in the case of the Moon.

7. With the intention of simplifying the task of applying the different corrections for these (and many other) varying values to the tide at a given place, Lord Kelvin introduced what is known as the "Harmonic method". If this method is carefully studied it is remarkably simple.

8. We start off with the fact that, if the Earth were a smooth globe, and the Moon went round it at a uniform distance at a constant speed, and raised a tide directly underneath it, then the tide at any place would rise and fall in the ratio of the cosine of twice the angle of the Moon's angular distance from the meridian. This can be expressed as:—Fall of tide = height above mean tide level $\times 2$ cos H.A. Moon. But if we imagine a Moon moving at twice the speed of the actual Moon then we can use the cos H.A. We therefore have an imaginary Moon called M_2 which is imagined to be at a uniform distance from the Earth and moving at a constant speed twice the speed of the actual Moon.

9. Similar to the fictitious body representing the Moon, we have another body, S_2, to represent the Sun's mean effect. We also have others to represent the difference in distance of the Moon, the changes in the Moon's declination, the changes in the Sun's declination, and other factors that have to be considered. In the Harmonic method we consider 9 of these constituents—M_2—S_2—N_2—K_2—K_1—O_1—P_1—M_4—MS_4.

The figure represents the number of times the factor affects the tide in one tidal day. M_2, S_2, N_2, K_2 are the semidiurnal factors; K_1, O_1, P_1 are the diurnal factors; and M_4, MS_4 are the quarter diurnal factors. These factors are called "Constituents".

10. By analysing the tide at a place, experts are able to calcu-

late how much each one of the factors affects the sea level at that place. These effects are called the height constants for that place. Another thing they are able to calculate is what may be called the hour angle of a body when its maximum effect will take place. This practically corresponds to the "Interval" and is given in degrees and called the "g" of the constituent at that place. It is sometimes called the "lag".

11. The "Harmonic" method calculates how much each constituent takes its effect above or below mean sea level; consequently this effect can be either plus or minus. So that we can apply the result to chart datum we are given the distance that mean sea level at a place is above chart datum. This is shown as A_o.

12. The final point to make clear is that, since all constituents travel at a constant speed, we can easily find their angular distance from the meridian at any moment if we are told where they are at a given time. We are given their positions at 00 hours in the first day of each month in any given year (this is called the "m" of the constituent). Knowing their hourly rate, and consequently their daily rate, we can then have a table giving an additive correction for any number of days in the month. This will therefore be:—Angular hourly speed $\times$ 24 $\times$ number of days, but with all complete circles (360°) removed. The resultant quantities are tabulated as the "d" of the constituents.

13. To sum up:—

1. We assume each tidal effect is caused by a specified constituent.
2. We find the position of the body relative to the meridian at a given time. $(m+d.)$
3. We ascertain the angular distance between the meridian and the constituent's position at its high water. $(g.)$
4. By applying 3 to 2 we find the angular distance of the constituent from its high water position. $(m+d-g.)$
5. We ascertain the maximum height of the constituent's high water. (H.)
6. By multiplying H by cos $(m+d-g)$ we find the actual effect of that constituent on sea level at that time.
7. Finding the effects of all the nine constituents and then combining them, we find the total effect on sea level.
8. Applying this total effect to A_o we find the actual height of sea level above chart datum.

THE ADMIRALTY METHOD.

1. Certain disadvantages of the harmonic method, combined with certain limitations that it has, led Commander Warburg, R.N., and Dr. Doodson to evolve a new method that would be as accurate as the Harmonic method but speedier in working and more far reaching in its application. This new method is called the Admiralty method.

2. We still have the four principal constituents (M_2, S_2, K_1, O_1), but we also have certain non-harmonic values. The constituent that dealt with the Moon's variable distance from the Earth has been replaced by calculations governed by the Moon's "horizontal parallax"; because the parallax will vary with the distance. Certain effects such as the declination of the Sun can be directly linked up with the date.

3. The principles underlying the method are not so easily grasped as the principles of the Harmonic method, but a stereotyped method of working has been introduced and can be easily understood by the intelligent student. One form of working is used when finding the height of the tide at a place at a given time; and another form of working is used when finding the times and heights of high water at a place. In both cases we require A.T.T. II and A.T.T. III.

4. Except that we use the "H" and "g" of each of the four principal harmonic constituents, there is no similarity in working between the Harmonic and Admiralty methods. A_0 is common to both, but the Admiralty method uses M_0 and Z_0 as alternatives. M_0 is the distance that mean, or half tide, level is above chart datum. Z_0 is the distance that mean sea level is above chart datum. To all intents and purposes A_0, M_0, Z_0 are one and the same thing.

5. In all cases of working by the Admiralty method we require to know the time of the Moon's *first* transit on the day in question (irrespective as to whether the transit is inferior or superior), and the Moon's horizontal parallax at midday (12 hrs.). Both of these are given in A.T.T. II, page 168.

6. The following brief descriptions of the methods by which we obtain "height of tide at a given hour" and "times and heights of high water" are not to be looked upon as instructions for working.

The purpose is to give a brief outline of the processes by which the results are obtained. In a treatise of this kind it is neither necessary nor helpful to investigate the involved and intricate steps by which the different tables are compiled. The student should know the order and rotation of the working, but he does not need to know why the working gives the required result.

7. To find the height of the tide at a given time, we take the "g" of each constitutent at the place in question (A.T.T. II); we apply a quantity from Table I (A.T.T. III) and add a third quantity from Table 2 (A.T.T. III). We then convert the standard time into arc and subtract from it the adjusted "g" value. The result is the angular quantity required.

8. We next take the "H" of each constitutent (A.T.T. II), another quantity from Table 1 (A.T.T. III) and a third quantity from Table 2 (A.T.T. III). We multiply these three (or sometimes two) quantities together, and the result is the height factor required.

9. We now enter Table 6 (A.T.T. III) with the angle and height factor and extract the height of tide for each of the four constituents. Adding these four heights together and applying them to M_0 or Z_0 we get the actual rise of tide.

10. In the preceding explanation we have dealt with the angles and heights separately, but actually we take out their adjustments at the same time. The "g" factor and the "H" factor are alongside each other in the tables and it would be foolish not to take them out together. Nevertheless, the foregoing explanation is easier to grasp than it would be if we dealt with each "g" process and each "H" process alternately.

11. To find the times and heights of high and low waters, we proceed as far as the first three steps in finding height at a given time. But we now subtract the S_2 angle from the M_2 angle, and the K_1 angle from the O_1 angle. Next, we divide the M_2 height by the S_2 height, and the O_1 height by the K_1 height.

We now have two angles and two heights; the first angle and height being the semidiurnal factor, and the other being the diurnal factor.

12. Entering Table 3 (A.T.T. III) with the semidiurnal quantities we take out another angle and another height factor.

We add this new angle to the previous angle S_2, and we multiply this new height factor by the previous S_2 height factor. We thus have a new semidiurnal angle and height factor. We deal with the diurnal quantities in an exactly similar manner and obtain a new diurnal angle and height factor.

13. We now turn the angles into time and subtract the semidiurnal time from the diurnal time. Next, we divide the diurnal height by the semidiurnal height. We now have one time and one height quantity. With these two values we enter Table 4 (A.T.T. III) we take out four times and four corresponding heights.

14. To each of these times we add the semidiurnal time, and we multiply each of these heights by the semidiurnal height. These four times are those of the two high and two low waters. By adding M_0 or Z_0 to the heights we get the heights of the tide at high and low waters. As they are under their corresponding times it is obvious that the heights indicate which are the high and low water times.

15. If special accuracy is required we enter Table 5 (A.T.T. III) and add in the appropriate corrections. If the constituents of a place include a shallow water correction (in A.T.T. II) this is added to the final result. This may be important in rivers and estuaries, particularly as regards times, as a small difference in height about high or low water requires an appreciable time interval for the tide to make this.

Worked Example One

Form B. TO FIND THE HEIGHT OF THE TIDE AT ANY REQUIRED TIME

Place: Penzance Date: May 31st. 1939

		Required Standard Time:	10·0 = t (hours and tenths)
(M_0) A_0 or Mean Sea Level	9·7 ft. (from A.T.T. Part II)	* A.M. Moon's Transit:	10 34 (from A.T.T. Part II)
Seasonal Correction	" " " "	† Increment for t hours:	+ 20 mins.
Corrected Mean Sea Level	9·7 "	Adjusted Transit:	10 54

Moon's H.P.: 57·0 (from A.T.T. Part II)

	M_2	S_2	K_1	O_1
(1) Harmonic Constants from A.T.T. Part II ..	g 135° H 5·6 ft.	g 179° H 1·9 ft.	g 108° H 0·2 ft.	g 339° H 0·2 ft.
(2) Enter Table 1 with year and date	b −1° B 1·03	b −6° B 0·77	b 185° B 1·19	b 167° B 0·85
(3) Enter Table 2 with Adjusted Transit and H.P.	c 316° C 1·0	— — — —	— — C 1·0	c 316° C 1·0
(4) Add $(g+b+c)$; Multiply $(H \times B \times C)$	m 450° M 5·8 ft.	s 173° S 1·5 ft.	k 293° K 0·2 ft.	o 822° O 0·2 ft.
(5) Convert Required Standard Time into angle	$t \times 30$ = 300° = t_m	$t \times 30$ = 300° = t_s	$t \times 15$ = 150° = t_k	$t \times 15$ = 150° = t_o
(6) Line (5) (angle) minus Line (4) (angle). ..	$t_m - m$ = −150° = d_m	$t_s - s$ = +127° = d_s	$t_k - k$ = −143° = d_k	$t_o - o$ = −672° = d_o
(7) Add or subtract 360° or 720°, where necessary to make line (6) between 0° and −360° ..	+360 d_m = 210°	000 d_s = 127°	+360 d_k = 217°	+720 d_o = 048°
(8) Enter Table 6 with Heights from Line (4) and angles from Line (7)	−5·0 ft.	−0·9 ft.	−0·2 ft.	+0·1 ft.
Height of Tide = Corrected Mean Sea Level + Sum of Heights in Line (8)	9·7 − 6·0 = 3·7			

Tables 1, 2 and 6 will be found in A.T.T. Part III

* A.M. Transit when there are two on the day, only transit when one

† Add 2 minutes for each hour of Required Standard Time counting from 0000, e.g. if Required Time is 1630 (t = 16.5) increment is +33 mins.

1939, May 31, at 10 hr. 00 min. standard time off Penzance. Required the height of tide.

Remarks.

Use Form B.

Take out Moon's transit for required data; also Moon's H.P. (this is obtained from the astronomical data in A.T.T. II.).

To the Moon's transit add the increment for 10 hr. standard time; that is, 2 min. for every hour thus 10×2 min. $=$ 20 min. which gives the adjusted transit.

The mean sea level A_o (or M_o) is taken out from the data for Penzance in A.T.T. II; as there is no † in the reference column there is no seasonal correction to apply.

Line 1. The harmonic constants for Penzance, A.T.T. II.

Line 2. Is Table 1 in A.T.T. III.

Line 3. Is Table 2 in A.T.T. III.

Line 4. Add $(g+b+c)$. Mult. $(H \times B \times C)$ to one decimal place.

Line 5. For M_2 and S_2 which are semidiurnal constants multiply standard time in hours and tenths by 30. For K_1 and O_1 which are diurnal constants multiply standard time by 15. (It should be fairly obvious that the values for K_1 and O_1 will be half the values for M_2 and S_2.)

Line 6. This is line 5 minus line 4 and a certain amount of care is required here because it is awkward to subtract "upside down". However, it will soon be seen that if line 4 is greater than line 5, then subtract line 5 from line 4 and call this a minus quantity; if line 4 is less than line 5 then we are left with a plus quanitity.

Line 7. If any quantities in line 6 are minus then add + 360 or + 720 to them so that the result lies between + 000° and +360°. (It sometimes happens that a value in line 6 is positive but over 360, *e.g.* + 380. In this case we must drop 360 from it, leaving + 020, that is, we have really applied − 360° to it.) For the sake of clearness we have, in the worked example, shown the application of the 360 and 720; but with practice this will hardly be necessary. However, the candidate should please himself in this matter as it is undoubtedly safer to show the working.

It may be helpful to the beginner, at first, to work the subtraction of line 4 from line 5 in the following way, thus avoiding line 6 altogether.

Write down line 5 on scrap paper (or the back of the form will do) and place *below* it line 4. Before subtracting, add to line 5 360° or 720° to increase it to a greater value than line 4. On subtracting we get line 7 direct.

Line 5.	300	300	150	150
	+360	+000	+360	+720
	660	300	510	870
Line 4.	450	173	293	822
Line 7.	210	127	217	048

Line 8. Table 6 A.T.T. III gives the value D cos d^1 which is the natural cosine of the angle in line 7 multiplied by the ½ range of the constituent line 4. As a cosine is negative between 90° and 270°, the values obtained from the table are negative where the angle lies between 90° and 270° and are positive for other angles.

It will be seen that the value for D is given up to 6 ft. only, and as we often require values for D in excess of 6 ft. some simple

multiple must be used. Suppose D was 8 ft. then we could take out a value for 4 ft. and double it. A more ingenious method would be to take out the value for 1 ft. (this is really the natural cosine of the angle) and multiply by the required D. This might not be quite so accurate, however, as the cosine is given for one decimal place only; so that it is probably best to use as small a multiple as possible such as half or one-third.

Height of Tide. The algebraic sum of the values in line 8 are now applied to the corrected mean sea level which gives the required height of tide.

It may be helpful at first to remember that the data up to line 1 (inclusive) are found in A.T.T. II; after line 1 data are in A.T.T. III.

Worked Example 2.

1939, June 14, at 17 hr. G.M.T. off Darwin. Required height of tide.

REMARKS.

Use Form B.

It will be seen that standard time at Darwin is (ST. — 0930) so that we must + 09 hr. 30 min. to G.M.T. to obtain standard time of cast. Therefore standard time of cast is—

June 15 at 02 hr. 30 min.

In the reference column for Darwin there is a † which indicates a seasonal correction to mean sea level.

This amount is obtained in A.T.T. II, Table 2. (The seasonal correction is given for the first of the calendar month so that we must interpolate for June 15. This is, however, a very simple matter.)

The meridian passage of the Moon is taken out for the standard time data, of course, and the increment for 2½ hours is 5 minutes; that is, 2 minutes for each hour of standard time.

Lines 1, 2, 3 and 4 are now taken out similarly to Worked Example 1. Where there is any doubt in interpolating between two values always take the higher answer, *e.g.* suppose we require the mid value between 270 and 275 this is 272·5; we should take 273 as the best solution as angles are only required to the whole degree.

Line 5 is now found, as in Worked Example 1, by multiplying

Worked Example Two

Form B. TO FIND THE HEIGHT OF THE TIDE AT ANY REQUIRED TIME

Place: *Darwin. June 14th. 17th. G.M.T. 1939* Date: *June 15th.*

A, or Mean Sea Level:	*12·6* ft. (from A.T.T. Part II)	Required Standard Time:	*02·5* = t (hours and tenths)
Seasonal Correction:	*+0·8* " " " "	* A.M. Moon's Transit:	*10 02* (from A.T.T. Part II)
Corrected Mean Sea Level:	*13·4* "	† Increment for t hours:	*+ 5* mins.
		Adjusted Transit:	*10 07*

Moon's H.P.: *58·3* (from A.T.T. Part II)

	M_2	S_2	K_1	O_1
(1) Harmonic Constants from A.T.T. Part II	g 158° H 6·6 ft.	g 217° H 3·4 ft.	g 348° H 1·9 ft.	g 315° H 1·1 ft.
(2) Enter Table 1 with year and date	b −1° B 1·03	b +1° B 0·74	b 179° B 1·24	b 181° B 0·85
(3) Enter Table 2 with Adjusted Transit and H.P.	c 294° C 1·07	— — — —	— — C 1·04	c 294° C 1·07
(4) Add $(g+b+c)$; Multiply (H×B×C)	m 451° M 7·3 ft.	s 218° S 2·5 ft.	k 527° K 2·4 ft.	o 790° O 1·0 ft.
(5) Convert Required Standard Time into angle ..	$t \times 30$ = 075° = t_m	$t \times 30$ = 075° = t_s	$t \times 15$ = 038° = t_k	$t \times 15$ = 038° = t_o
(6) Line (5) (angle) minus Line (4) (angle).. ..	$t_m - m$ = −376° = d_m	$t_s - s$ = −143° = d_s	$t_k - k$ = −489° = d_k	$t_o - o$ = −752° = d_o
(7) Add or subtract 360° or 720°, where necessary to make line (6) between 0° and +360° ..	+720 d_m = 344°	+360 d_s = 217°	+720 d_k = 231°	+1080 d_o = 328°
(8) Enter Table 6 with Heights from Line (4) and angles from Line (7)	+7·0 ft.	−2·0 ft.	−1·5 ft.	+0·8 ft.
Height of Tide = { Corrected Mean Sea Level + Sum of Heights in Line (8)	13·4 + 4·3 = 17·7			

Tables 1, 2 and 6 will be found in A.T.T. Part III.

* A.M. Transit when there are two on the day, only transit when one.

† Add 2 minutes for each hour of Required Standard Time, counting from 0000, *e.g.* if Required Time is 1630 (t = 16·5) increment is +33 mins.

the standard time in hours and tenths by 30° for M_2 and S_2 and by 15° for O_1 and K_1.

As $2 \cdot 5 \times 15 = 037 \cdot 5$ we take the higher value 038 as the solution.

Now line 4 is subtracted from line 5 as before.

Line 7. For the O_1 value − 752 it is necessary to apply + 1080; that is, 3 times 360° to reduce it to between 0° and +360°. This value 1080 is not mentioned on the Admiralty form B as it is unusual and, of course, could be avoided expertly by judiciously trimming line 4 of a surplus 360° or 720°.

Line 8. We cannot in Table 6 pick out a value for 7·3 ft. direct as required for M_2, but we can take out a value for half 7·3 and double the extract. It is not particularly accurate this, but there is nothing better to do until the authorities extend the table. In any case, for tidal work we must not be too finicky about an odd tenth of a foot or so.

Worked Example Three

Form B. TO FIND THE HEIGHT OF THE TIDE AT ANY REQUIRED TIME

Place. *Dover at L.M.T. 0005* Date: *July 1st. 1939*

A₀ or Mean Sea Level	*9·3* ft.	…m A.T.T. Part II)	Required Standard Time:	*00 00* = t (hours and tenths)
Seasonal Correction	*—*	" " "	* A.M. Moon's Transit:	*11 54* (from A.T.T. Part II)
Corrected Mean Sea Level	*9·3* "		† Increment for t hours:	*+ 0* mins.
			Adjusted Transit:	*11 54*

Moon's H.P.: *54·9* (from A.T.T. Part II)

	M_2	S_2	K_1	O_1
(1) Harmonic Constants from A.T.T. Part II	g *330°* H *7·3* ft.	g *021°* H *2·3* ft.	g *039°* H *0·1* ft.	g *175°* H *0·2* ft.
(2) Enter Table 1 with year and date	b *−1°* B *1·03*	b *08°* B *0·77*	b *172°* B *1·22*	b *197°* B *0·85*
(3) Enter Table 2 with Adjusted Transit and H.P.	c *345°* C *0·90*	*— — — —*	*— —* C *0·93*	c *345°* C *0·90*
(4) Add (g + b + c), Multiply (H × B × C)	m *674°* M *6·8* ft.	s *029°* S *1·8* ft.	k *211°* K *0·1* ft.	o *717°* O *0·2* ft.
(5) Convert Required Standard Time into angle	t × 30 = *000°* = t_m	t × 30 = *000°* = t_s	t × 15 = *000°* = t_k	t × 15 = *000°* = t_o
(6) Line (5) (angle) minus Line (4) (angle)	$t_m - m$ = *−674°* = d_m	$t_s - s$ = *−029°* = d_s	$t_k - k$ = *−211°* = d_k	$t_o - o$ = *−717°* = d_o
(7) Add or subtract 360° or 720°, where necessary to make line (6) between 0° and −360°	*+720* d_m = *046°*	*+360* d_s = *331°*	*+360* d_k = *149°*	*+720* d_o = *003°*
(8) Enter Table 6 with Heights from Line (4) and angles from Line (7)	*+4·8* ft.	*+1·6* ft.	*−0·1* ft.	*+0·2* ft.
Height of Tide = { Corrected Mean Sea Level + Sum of Heights in Line (8) }	*9·3 + 6·5 = 15·8*			

Tables 1, 2 and 6 will be found in A.T.T. Part III.

* A.M. Transit when there are two on the day, only transit when one.

† Add [illegible] minutes for each hour of Required Standard Time counting from 0000, e.g. if Required Time is [illegible] increment is [illegible] mins.

TO FIND THE HEIGHT OF TIDE AT ANY REQUIRED TIME. Form B.

1. 1939, March 5, at 03 hr. 00 min. standard time off Dover. Required height of tide.
2. 1939, December 31, at 23 hr. 30 min. G.M.T. off Ramsgate. Required height of tide.
3. 1939, July 4, at 05 hr. 30 min. G.M.T. off Sandy Hook. Required height of tide.
4. 1939, June 1, at 07 hr. 12 min. L.M.T. off Darwin. Required correction to apply to lead line to reduce sounding to chart datum.
5. 1939, April 4, at 23 hr. 00 min. standard time off Hartlepool. Required height of tide.
6. 1939, July 1, at 03 hr. 00 min. G.M.T. off Dublin North Wall. Required height of tide.

7. 1939, March 28, at noon S.M.T. off London Bridge. Required height of tide.

8. 1939, January 5, at 03 hr. 00 min. standard time the vertical sextant angle off Devonport Lighthouse (194 ft., M.H.W.S. 18·4 ft.) was 1° 00′. Required distance off.

9. 1939, January 31, at noon G.M.T. off Nomuka. Required height of tide.

10. 1939, May 31, at 10 hr. 00 min. L.M.T. off Macquarie Island. Required height of tide.

11. 1939, February 10, at 14 hr. 00 min. standard time off Thursday Island Harbour. What depth of water will there be over a rock marked (dries 2 ft.)?

12. 1939, February 18, at 02 hr. 10 min. G.M.T. off St. John, Bay of Fundy. Required height of tide.

13. 1939, September 6, at 19 hr. 42 min. G.M.T. off Wilhelmshaven. Required height of tide.

14. 1939, March 22, at 20 hr. 12 min. G.M.T. off Dover. Required height of tide.

15. 1939, July 10, at 04 hr. 00 min. B.S.T. off Penzance. Required correction to apply to lead line before comparing sounding with datum on the chart.

16. 1939, February 20, at 00 hr. 00 min. standard time off Bahia Blanca (Puerto Belgrano). Required height of tide.

Worked Example I.

Form A. TO FIND TIMES AND HEIGHTS OF HIGH AND LOW WATER

Place	*Middlesbrough*	Date	*May 31st.*
A_0 or Mean Sea Level .	*9·1* ft. (from A.T.T. Part II)	* A.M. Moon's Transit .	*10 34* (from A.T.T. Part II)
Seasonal Correction :	" " " "	Increment :	+ 24 min.
Corrected Mean Sea Level :	*9·1* "	Adjusted Transit .	*10 58*

Moon's H.P.: *57·0* (from A.T.T. Part II)

	M_2	S_2	K_1	O_1
(1) Harmonic Constants from A.T.T. Part II	g *113*° H *5·2* ft	g *152*° H *1·7* ft.	g *261*° H *0·4* ft	g *104*° H *0·4* ft.
(2) Enter Table 1 with year and date ..	b *−1*° B *1·03*	b *−6*° B *0·77*	b *185*° B *1·19*	b *167*° B *0·85*
(3) Enter Table 2 with Adjusted Transit and H.P.	c *318*° C *1·0*	— — — —	— — C *1·0*	c *318*° C *1·0*
(4) Add $(g-b+c)$. Multiply $(H \times B \times C)$	m *430*° M *5·4* ft	s *146*° S *1·3* ft	k *446*° K *0·5* ft	o *589*° O *0·3* ft.
	SEMIDIURNAL TIDE		DIURNAL TIDE	
(5) From Line (4) { Add or subtract 360° or 720° if necessary	$d_2 = m - s$; $D_2 = \frac{M}{S}$	d_2 *284*° D_2 *4·2* ft	d_1 *143*° D_1 *0·6* ft.	$d_1 = o - k$; $D_1 = \frac{O}{R}$
(6) Enter Table 3 with d and D from Line (5) .		e_2 *297*° E_2 *4·5*	e_1 *035*° E_1 *0·7*	
(7) From Lines (6) and (4) .	$f_2 = e_2 + s$; $F_2 = E_2 \times S$	f_2 *443*° F_2 *5·9* ft	f_1 *481*° F_1 *0·4* ft	$f_1 = e_1 + k$; $F_1 = E_1 \times K$
(8) Subtract 360° or 720° if necessary to reduce f_2, f_1 below 360°		f_2 *083*° —	f_1 *121*° —	
(9) Convert f_2 and f_1 angles into time : $\frac{f_2}{30}$, $\frac{f_1}{15}$ ..		f_2 *2·8* hrs —	f_1 *8·1* hrs. —	

COMBINED SEMIDIURNAL AND DIURNAL TIDE						
(10) From Line (9) ..	$j = (f_1 - f_2)$ hrs.; add 24 hrs if negative	j *5·3* hrs				
From Line (7) ..	$J = \frac{F_1}{F_2}$	J *nil*				
(11) Enter Table 4 with j and J ..		Time (l)	*0* hrs	*6* hrs.	*12* hrs	*18* hrs.
		Factor (L)	*1*	*−1*	*1*	*−1*
(12) From Lines (11) and (9)	$g = (l + f_2)$ hrs.	Time (g)	*2·8* hrs	*8·8* hrs.	*14·8* hrs.	*20·8* hrs.
From Lines (11) and (7)	$Q = (L \times F_1)$ ft	Height (Q)	*5·9* ft	*−5·9* ft	*5·9* ft	*−5·9* ft
(13) Times and Heights of High and Low Water †(Subtract 24 hrs. from times if necessary)	† g in hours and minutes	Time	*2* h *48* m	*8* h *48* m	*14* h *48* m	*20* h *48* m
	Q + Corrected Mean Sea Level	Height	*15·0* ft	*3·2* ft	*15·0* ft	*3·2* ft
(14) If special accuracy is required, enter Table (5) for S_2 with d_2 and D_2 from Line (5),		‡ Corrections	*−16* m	*−5* m	*5* m	*15* m
and enter Table 5 for K_1 with d_1 and D_1. Deduce corrections to Times		Corrd Times	*2* h *32* m	*8* h *43* m	*14* h *53* m	*21* h *03* m
§ (15) Times from Line (14), Heights from Line (13)		h m ft	h m ft	h m ft	h m ft	
Shallow Water Corrections (from A.T.T. Part II)						
(16) Shallow Water Predictions		h m ft	h m ft	h m ft	h m ft	

Tables 1 to 5 will be found in A.T.T. Part III.

* A.M. Transit when there are two on the day, only transit when one

† Tides from which 24 hours have been subtracted become first tides of the day

‡ If correction per hour is positive, subtract from a.m. add to p.m. tides: if negative, add to a.m. subtract from p.m. tides. Total correction is: Correction per hour × interval from 1200

§ This step will only be necessary if Shallow Water Corrections are given in A.T.T. Part II

Worked Example 1.

Required the times and heights of high and low water on May 31, 1939, at Middlesbrough.

REMARKS.

The increment to the Moon's transit is a constant of 24 min. We always assume the increment for midday or 12 hours. H.P. and mean sea level are taken out in the ordinary way.

Lines 1, 2, 3 and 4 are as usual. It should be noted that small letters denote values for times and that capital letters are used for heights.

Now comes the first combination. Firstly, to combine M_2 and S_2 into the semidiurnal tide. Secondly, to combine K_1 and O_1 into the diurnal tide.

Thus $m - s$ and $\frac{M}{S}$ give 284° and 4·2 ft.

and $o - k$ and $\frac{O}{K}$ give 143° and 0·6 ft.

Before these values can be applied to S and K we must convert *d* values into *e* values. (Table 3.)

$$\text{And now } f_2 = e_2 + s\,;\ F_2 = E_2 \times S$$
$$\text{also } f_1 = e_1 + k\,;\ F_1 = E_1 \times K$$

f_2 and f_1 are reduced to below 360° by subtracting 360° or 720° as necessary, then divided by 30° and 15° respectively (these being the angular speeds per hour of semidiurnal and diurnal constituents).

We now have the constituents combined to—

f_2 2·8 hrs.; F_2 5·9 ft.; and f_1 8·1 hrs.; and F_1 0·4 ft.

The final combination is now entered upon.

The semidiurnal time is subtracted from the diurnal time—

$f_1 - f_2 = 5{\cdot}3$ hours (j)

The semidiurnal height is divided *into* diurnal height—

$F_1 \div F_2 =$ Nil (J) (the value being less than 0·1)

Now the *combinations* of the constituents being concluded we now commence the reverse process; that is, to *resolve* j and J into the four tides for the day.

Line 11 is the first step, Table 4 combining the tides of different species. (l and L.)

Line 12. $q = (l + f_2)$ hrs.; $Q = L \times F_2$ ft.

(Be careful to use the semidiurnal values.)

Line 13. q for line 12 is now written down in hours and minutes instead of the hours and decimals as hitherto used throughout the working, and we have the approximate times of high and low water for the day.

Q for line 12 must be applied to corrected mean sea level and this gives the required heights of tide. In this example the tides work out in the proper rotation for the day; that is, the first tide of the day is H.W. 2 hr. 48 min., 15·0 ft., then L.W. 08 hr. 48 min., 3·2 ft. etc. However, in a number of cases the tides will have to be sorted out from line 13 and put in proper rotation for the day where this is required for any particular reason. It will never be in doubt which is the high and which the low water from the computed heights.

Line 14. *Special Accuracy Predictions.* See explanation on Form A. Where special accuracy is required the formula in conjunction with Table 5 supplies the supplementary corrections to the times of high and low water.

$$\text{Correction} = \text{Interval time of tide is from 12 h} \times \frac{(S_2 \text{ corr} \times F_2) + (K_1 \text{ corr} \times F_1)}{F_2 + F_1}$$

$$= \text{Interval etc.} \times \frac{(1{\cdot}9 \times 5{\cdot}9) + (-1{\cdot}4 \times 0{\cdot}4)}{5{\cdot}9 + 0{\cdot}4}$$

$$= \text{Interval etc.} \times \frac{(11{\cdot}2) + (-0{\cdot}6)}{6{\cdot}3}$$

$$= \text{Interval etc.} \times \frac{10{\cdot}6}{6{\cdot}3}$$

$$= \text{Interval etc.} \times 1{\cdot}7$$

Approx. H.W. 2h 48m

Correction $= (12\text{h} \sim 2{\cdot}8) \times 1{\cdot}7$

$= 9{\cdot}2 \times 1{\cdot}7 = 16\text{m}$ (minus to A.M. tide)

Approx. L.W. 08h 48m

$= (12\text{h} \sim 8{\cdot}8) \times 1{\cdot}7$

$= 3{\cdot}2 \times 1{\cdot}7 = 5\text{m}.$ (minus to A.M. tide)

Approx. H.W. 14h 48m

$= (12 \sim 14{\cdot}8) \times 1{\cdot}7$

$= 2{\cdot}8 \times 1{\cdot}7 = 5\text{m}$ (plus to P.M. tide)

Approx. L.W. 20h 48m

$= (12 \sim 20{\cdot}8) \times 1{\cdot}7$

$= 8{\cdot}8 \times 1{\cdot}7 = 15\text{m}$ (plus to P.M. tide)

Thus required times and heights of high and low water at Middlesbrough on May 31, 1939, are—

Middlesbrough	High Water			Low Water		
May 31	02h	32m	15·0ft.	08h	43m	3·2 ft
	14	53	15·0	21	03	3·2

There is no asterisk (*) in the reference column for Middlesbrough hence there are no shallow water corrections to apply to the above.

Worked Example 2

Form A. TO FIND TIMES AND HEIGHTS OF HIGH AND LOW WATER

Place *London Bridge* Date *March 28th 1939*

A$_0$ or Mean Sea Level : *11·0* ft. (from A.T.T. Part II) — * A.M. Moon's Transit : *05 55* (from A.T.T. Part II)

Seasonal Correction " " " " — Increment + 24 min

Corrected Mean Sea Level : *11·0* " — Adjusted Transit *06 19*

Moon's H.P. : *58·9* (from A.T.T. Part II)

	M_2		S_2		K_1		O_1	
(1) Harmonic Constants from A.T.T. Part II	g *036°*	H *8·0* ft.	g *102°*	H *2·2* ft.	g *036°*	H *0·4* ft.	g *213°*	H *0·4* ft.
(2) Enter Table 1 with year and date	b *−1°*	B *1·03*	b *−2°*	B *1·2*	b *249°*	B *·61*	b *103°*	B *·85*
(3) Enter Table 2 with Adjusted Transit and H.P.	c *184°*	C *1·1*	— —	— —	— —	C *1·07*	c *184°*	C *1·1*
(4) Add $(g+b+c)$; Multiply $(H \times B \times C)$ ..	m *219°*	M *9·1* ft.	s *100°*	S *2·6* ft.	k *285°*	K *0·3* ft.	o *500°*	O *·4* ft.
	SEMIDIURNAL TIDE				DIURNAL TIDE			
(5) From Line (4) {Add or subtract 360° or 720° if necessary	$d_2 = m - s$; $D_2 = \frac{M}{S}$		d_2 *119°*	D_2 *3·5* ft.	d_1 *215°*	D_1 *1·3* ft.	$d_1 = o - k$; $D_1 = \frac{O}{K}$	
(6) Enter Table 3 with d and D from Line (5)			e_2 *103°*	E_2 *3·1*	e_1 *265°*	E_1 *0·8*		
(7) From Lines (6) and (4)	$f_2 = e_2 + s$; $F_2 = E_2 \times S$		f_2 *203°*	F_2 *8·1* ft.	f_1 *550°*	F_1 *0·2* ft.	$f_1 = e_1 + k$; $F_1 = E_1 \times K$	
(8) Subtract 360° or 720° if necessary to reduce f_2, f_1 below 360°			f_2 *203°*	—	f_1 *190°*	—		
(9) Convert f_2 and f_1 angles into time : $\frac{f_2}{30}$, $\frac{f_1}{15}$ ..			f_2 *6·8* hrs.	—	f_1 *12·7* hrs.	—		
	COMBINED SEMIDIURNAL AND DIURNAL TIDE							
(10) From Line (9) .. .. From Line (7)	$j = (f_1 - f_2)$ hrs.; add 24 hrs. if negative $J = \frac{F_1}{F_2}$			j *5·9* hrs. J *0·0*				
(11) Enter Table 4 with j and J				Time (l) Factor (L)	*0* hrs. *1·0*	*6* hrs. *−1·0*	*12* hrs. *1·0*	*18* hrs. *−1·0*
(12) From Lines (11) and (9) .. .. .. From Lines (11) and (7)	$q = (l + f_2)$ hrs. $Q = (L \times F_2)$ ft.			Time (q) Height (Q)	*6·8* hrs. *8·1* ft.	*12·8* hrs. *−8·1* ft.	*18·8* hrs. *+8·1* ft.	*0·8* hrs. *−8·1* ft.
(13) Times and Heights of High and Low Water (Subtract 24 hrs. from times if necessary)	† q in hours and minutes Q + Corrected Mean Sea Level			Time Height	*6* h.*48*m. *19·1* ft.	*12* h *48*m *2·9* ft.	*18*h.*48*m. *19·1* ft.	*0*h *48*m *2·9* ft.
(14) If special accuracy is required, enter Table (5) for S_2 with d_2 and D_2 from Line (5); and enter Table 5 for K_1 with d_1 and D_1. Deduce corrections to Times				‡ Corrections Corrd Times	*−11* m. *6* h.*37*m	*+2* m. *12*h. *50*m	*+15* m *19*h *03*m	*−24* m. *0* h.*24*m
§ (15) Times from Line (14), Heights from Line (13) Shallow Water Corrections (from A.T.T. Part II)	*6* h.*37*m. *+03*	*19·1* ft. *+1·1*	*12*h.*50*m. *+00 27*	*+2·9* ft. *−1·1*	*19*h. *03*m. *+03*	*19·1* ft. *+1·1*	*0*h.*24*m *+00 27*	*2·9* ft. *−1·1*
(16) Shallow Water Predictions	*6* h.*40*m.	*20·2* ft.	*13*h. *17*m.	*1·8* ft.	*19*h. *06*m	*20·2* ft.	*0*h *51*m	*1·8* ft.

Tables 1 to 5 will be found in A.T.T. Part III

* A.M. Transit when there are two on the day, only transit when one.

† Tides from which 24 hours have been subtracted become first tides of the day.

‡ If correction per hour is positive, subtract from a.m., add to p.m. tides; if negative, add to a.m., subtract from p.m. tides. Total correction is Correction per hour × interval from 1200.

§ This step will only be necessary if Shallow Water Corrections are given in A.T.T. Part II.

Worked Example 3.

Form A. TO FIND TIMES AND HEIGHTS OF HIGH AND LOW WATER

Place *Pakhoi.* Date *January 8th 1939*

A_0 or Mean Sea Level	*9·7* ft. (from A.T.T. Part II)	* A.M. Moon's Transit :	*02 09* (from A.T.T. Part II)
Seasonal Correction	" " " "	Increment :	– 24 min
Corrected Mean Sea Level	*9·7* "	Adjusted Transit :	*02 33*

Moon's H.P.: *60·7* (from A.T.T. Part II)

	M_2	S_2	K_1	O_1
(1) Harmonic Constants from A.T.T. Part II	g *164°* H *1·3* ft.	g *201°* H *0·4* ft.	g *072°* H *3·1* ft.	g *038°* H *3·4* ft.
(2) Enter Table 1 with year and date	b *–1°* B *1·03*	b *10°* B *·93*	b *347°* B *1·17*	b *26°* B *·85*
(3) Enter Table 2 with Adjusted Transit and H.P.	c *74°* C *1·20*	— — — —	— — C *1·14*	c *74°* C *1·20*
(4) Add (g – b + c). Multiply (H × B × C) ..	m *237°* M *1·6* ft.	s *211°* S *0·4* ft.	k *419°* K *4·1* ft.	o *138°* O *3·5* ft.
	SEMIDIURNAL TIDE		DIURNAL TIDE	
(5) From Line (4) { Add or subtract 360° or 720° if necessary	$d_2 = m - s$; $D_2 = \frac{M}{S}$	d_2 *026°* D_2 *4·0* ft.	d_1 *079°* D_1 *0·9* ft.	$d_1 = o - k$ $D_1 = \frac{O}{K}$
(6) Enter Table 3 with d and D from Line (5) ..		e_2 *021°* E_2 *4·9*	e_1 *38°* E_1 *1·5*	
(7) From Lines (6) and (4)	$f_2 = e_2 + s$; $F_2 = E_2 \times S$	f_2 *232°* F_2 *2·0* ft.	f_1 *457°* F_1 *6·2* ft.	$f_1 = e_1 + k$ $F_1 = E_1 \times K$
(8) Subtract 360° or 720° if necessary to reduce f_2, f_1 below 360°		f_2 *232°* —	f_1 *97°* —	
(9) Convert f_2 and f_1 angles into time $\frac{f_2}{30}, \frac{f_1}{15}$ ..		f_2 *7·7* hrs. —	f_1 *6·5* hrs. —	

	COMBINED SEMIDIURNAL AND DIURNAL TIDE					
(10) From Line (9) .. .. / From Line (7)	$j = (f_1 - f_2)$ hrs.; add 24 hrs. if negative / $J = \frac{F_1}{F_2}$	j *22·8* hrs. / J *3·1*				
(11) Enter Table 4 with j and J		Time (l) / Factor (L)	*8·5* hrs / *–2·7*	— hrs / —	— hrs / —	*23·6* hrs / *4·0*
(12) From Lines (11) and (9) .. .. .. / From Lines (11) and (7)	$q = (l + f_2)$ hrs. / $Q = (L \times F_2)$ ft.	Time (q) / Height (Q)	*16·2* hrs / *–5·4* ft	— hrs / — ft	— hrs / — ft	*7·3* hrs. / *8·0* ft
(13) Times and Heights of High and Low Water (Subtract 24 hrs. from times if necessary) †	q in hours and minutes / Q + Corrected Mean Sea Level	Time / Height	*16*h *12*m / *4·3* ft	– h – m / — ft	– h – m / — ft	*7*h *18*m. / *17·7* ft.
(14) If special accuracy is required, enter Table (5) for S_2 with d_2 and D_2 from Line (5), and enter Table 5 for K_1 with d_1 and D_1. Deduce corrections to Times		‡ Corrections / Corrd. Times	*+ 7* m / *16*h *19*m	— m / – h – m	— m / – h – m	*– 8* m / *7*h *10*m
(15) § Times from Line (14) Heights from Line (13) / Shallow Water Corrections (from A.T.T. Part II)	h m	ft	h m	ft	h m	ft	h m	ft
(16) Shallow Water Predictions	h m	ft	h m	ft	h m	ft	h m	ft

Tables 1 to 5 will be found in A.T.T. Part III

* A.M. Transit when there are two on the day, only transit when one

† Tides from which 24 hours have been subtracted become first tides of the day

‡ If correction per hour is positive, subtract from a.m., add to p.m. tides; if negative, add to a.m., subtract from p.m. tides. Total correction is Correction per hour × interval from 1200

§ This step will only be necessary if Shallow Water Corrections are given in A.T.T. Part II

TO FIND TIMES AND HEIGHTS OF HIGH AND LOW WATER. FORM A.

1. Place: Burncoat Head.	Date: April 22, 1939.
2. Place: Penzance.	Date: March 21, 1939.
3. Place: Immingham.	Date: January 1, 1939.
4. Place: Pakhoi.	Date: January 7, 1939.
5. Place: Dover.	Date: March 23, 1939.
6. Place: Southampton.	Date: April 6, 1939.
7. Place: Hartlepool.	Date: September 27, 1939.
8. Place: Devonport.	Date: January 5, 1939.
9. Place: Port Darwin.	Date: April 3, 1939.
10. Place: Dover.	Date: September 29, 1939
11. Place: Port Darwin.	Date: March 28, 1939.

ANSWERS.

Examples for Practice No. 1.

1.	10h	17	3.	16h	06	5.	15h	27m
2.	04	23	4.	14	00	6.	09	55

Examples for Practice No. 2.

1.		13h	00m	5.	06h	03m
2.		20	28	6.	09	00
3.		00	00	7.	12	03
4.	22d	00h	05m	8.	06	00

Examples for Practice No. 3.

1. January 7 1904 and January 8 0122 (tide falling).
2. January 3 2149 and January 4 0401 (tide rising).
3. May 20 1909 and May 21 0003 (tide rising).
4. May 26 1651 and May 27 0015 (tide falling).
5. January 11 2203 and January 12 0416 (tide falling).

Examples for Practice No. 4.

	θ		θ
1.	30° from H.W.	4.	32° from H.W.
2.	60° from L.W.	5.	90° from H. and L. water
3.	29° from L.W.	6.	66° from H.W.

Examples for Practice No. 5.

Question 1. Interval from high water 01 hr. 01 min., duration of fall 7 hr. 14 min. $\theta=25°$, correction to high water—0·7 ft., correction to lead line—16·0 ft.

Question 2. As the interval from low water is only 10 min. the height of low water equals the height of the tide, *i.e.* 1·2 ft. below chart datum.

Question 3. Interval from low water 01 hr. 48 min., duration of rise 06 hr. 0 min., range 12·1 ft., $\theta=54°$, correction to low water+2·5 ft., correction to lead line =—4·4 feet.

Question 4. Interval from high water 3 hr. 14 min., duration of fall 06 hr. 28 min., range 7·4 ft., $\theta=90°$, correction to high water—3·7 ft., height of tide 8·3 ft.

NOTE.—It should be seen that time from low water is the same as time from high water, therefore the height of tide=mean tide level. This can be found by taking the half sum of the two heights.

Question 5. Interval from high water 01 hr. 30 min., duration of rise 06 hr. 23 min., range 18·4 ft., $\theta=43°$, correction to high water—2·5 ft., height of tide 17·2 ft.

Question 6. Interval from high water 00 hr. 38 min., duration of rise 05 hr. 45 min., range 7·5 ft., $\theta=20°$, correction to high water—0·2 ft., correction to lead line—7·7 ft.

Question 7. Long. correction+28 min., interval from high water 02 hr. 27 min., duration of fall 06 hr. 50 min., range 8·8 ft., θ=65°, correction to high water 2·6 ft., correction to lead line—6·2 ft.

Question 8. Long. correction—5 min., interval from low water 02 hr. 5 min., duration of rise 05 hr. 06 min., range 18·3 ft., θ=74°, correction to low water+6·6 ft., height of tide 6·4 ft., total depth over rock 18·4 ft.

Question 9. Long. correction—5 min., interval from low water 01 hr. 12 min., duration of rise 05 hr. 10 min., range 16·0 ft., θ=42°, correction to low water+2·1 ft., height of tide 3·7 ft.

Question 10. Long. correction+11 min., interval from low water 01 hr. 31 min., duration of rise 05 hr. 32 min., θ=49°, range 40·2 ft., correction to low water +6·9 ft., correction to lead line 8·6 to subtract.

Question 11. Long. correction+03 min., interval from high water 41 min., duration of rise 07 hr. 25 min., θ=16°, range 5·8 ft., correction to high water—0·1 ft., height of tide 6·2 ft., total depth 30·2 ft.

Question 12. Enter with 4 hours before high water at Dover.

Question 13. Interval from low water 01 hr. 11 min., duration of rise 06 hr. 02 min., range 17·4 ft., θ=35°, correction to low water+1·6 ft., height of tide 0·6 ft., total depth 24·6 ft.

Question 14. As the time from high water is only 7 minutes the height of high water= height of the tide, *i.e.* 21·2 ft.

Question 15. Intervals 02 hr. 0 min., 02 hr., 15 min., 02 hr. 30 min., 02 hr. 45 min., 03 hr. 00 min.; heights of tide 2·9 ft., 3·5 ft., 3·9 ft., 4·3 ft., 4·7 ft.; depths reduced to chart datum 41·1 ft., 44·5 ft., 47·1 ft., 51·7 ft., 56·3 ft., range 6·5 ft., duration of rise 05 hr., 40 min., θ 63°, 72°, 79°, 88°, 85°.

Question 16. Interval from low water 01 hr. 40 min., duration of rise 06 hr. 07 min., range 4·2 ft., θ=50°, correction to low water+·7 ft., height of tide 4·3 ft., total depth 19·3 ft.

Question 17. Interval from high water 01 hr. 30 min., duration of fall 06 hr. 31 min., range 7·3 ft. θ=42°, correction to high water—1·0 ft., height of tide 6·7 ft., height above sea level 161·8 ft.

Question 18. Interval from low water 01 hr. 20 min., duration of rise 05 hr. 33 min., range 21·2 ft., θ=44°, correction to low water+2·8 ft., height of tide 3·5 ft., depth at following low water 37·7 ft.

Question 19. Interval from high water 01 hr. 39 min., duration of fall 06 hr. 10 min., range 17·6 ft., θ=49°, correction to high water —3·0 ft., height of tide 27·1 ft. Tide has to fall 14·6 ft., therefore anchor in 50·6 ft.

Question 20. Time high water 00 hr. 38 min., height 18·5 ft., time low water 08 hr. 06 min., height 0·3 ft. below chart datum.

TO FIND TIME.

Examples for Practice No. 6.

Question 1. Duration of fall 06 hr. 19 min., range 13·0 ft., θ=51° correction 2·4 ft. interval 1 hr. 48 min., time of occurrence 18 hr. 18 min.

Question 2. Duration of rise 07 hr. 26 min., range 18·6 ft., θ=40°, correction 2·2 ft., interval 1 hr. 39 min. Time height occurs 06 hr. 34 min.

Question 3. Duration of rise 05 hr. 44 min., range 7·0 ft., $\theta=54°$, correction 1·4 ft., interval 1 hr. 44 min. Time there would be total depth is 15 hr. 59 min.

Question 4. Duration of fall 06 hr. 32 min., range 7·2 ft., correction 1·6 ft. $\theta=59°$, interval 2 hr. 8 min. Standard time 08 hr. 01 min., L.M.T. 07 hr. 33 min.

Question 5. Duration of fall 06 hr. 20 min., range 17·8 ft., correction 4·5 ft., $\theta=60°$, interval 2 hr. 6 min. Time 09 hr. 44 min., L.M.T. 09 hr. 27 min.

Question 6. Duration of rise 05 hr. 01 min., range 17·9 ft., correction 2 ft., $\theta=39°$, interval 1 hr. 5 min. after low water.

Question 7. Duration of fall 06 hr. 35 min., range 7·9 ft., correction 3 ft., $\theta=76°$. Time 2 hr. 47 min. after high water.

Question 8. Duration of rise 06 hr. 09 min., range 16·1 ft., correction 1 ft., $\theta=29°$, interval 1 hr. 00 min. after low water.

Question 9. Duration of fall 07 hr. 30 min., range 18·6 ft., correction 7 ft., $\theta=76°$, interval 3 hr. 10 min., latest time to leave 03 hr. 13 min.

Question 10. Duration of rise 06 hr. 05 min., range 16·9 ft., correction 4·8 ft., $\theta=64°$, interval 2 hr. 10 min. Time awash 02 hr. 43 min.

Question 11. Duration of fall 06 hr. 16 min., range 7·5 ft., correction from low water 2·0 ft., $\theta=62°$, interval 2 hr. 9 min., latest time 15 hr. 31 min.

Question 12. (1) Required height of tide when vessel grounded. Duration of rise 06 hr. 20 min., range 10·9 ft., interval from high water 2 hr. 44 min., $\theta=78°$, correction 4·4 ft., height of tide 6·8 ft.

(2) To find time when there will be height of tide of 4·8 ft., *i.e.* 6·8 ft.—2·0 ft. Duration 06 hr. 05 min., range 10·6 ft., correction from low water 4·5 ft., $\theta=82°$, interval from low water 02 hr. 47 min. Standard time when the ship will float 16 hr. 23 min.

Examples for Practice No. 7.

Q.	1.	1200	*Q.*	4.	1605
Q.	2.	1000	*Q.*	5.	2330 May 11th.
Q.	3.	1629			

Examples for Practice No. 8.

Q.	1.	1330	*Q.*	4.	1400
Q.	2.	0400	*Q.*	5.	1227
Q.	3.	2200 Feb. 16th	*Q.*	6.	0747

TIDAL DIFFERENCES.

Examples for Practice No. 9.

1. High water 03 hr. 04 min., 20·0 ft., low water 10 hr. 18 min., 1·9 ft., duration 7 hr. 14 min., range 18·1 ft., interval from high water 00 hr. 56 min., $\theta=23°$, height of tide 19·3 ft.

2. High water 11 hr. 48 min., 8·6 ft., low water 17 hr. 57 min., 0·4 ft., duration 6hr. 09 min., range 8·2 ft., interval from high water 00 hr. 57 min., $\theta=28°$, height of tide 0·9 ft.

3. High water 15 hr. 52 min., 16·0 ft., low water 9 hr. 39 min., 3·4 ft., duration 6 hr. 13 min., range 12·6 ft., interval from low water 02 hr. 31 min., $\theta=72°$, height of tide 7·7 ft.

4. High water 20 hr. 44 min., 40·4 ft., low water 15 hr. 21 min. 2·0 ft., duration 5 hr. 23 min., range 38·4 ft., interval from low water 02 hr. 07 min., $\theta=71°$, height of tide 15·0 ft.

5. High water 18 hr. 30 min., 12·5 ft., low water 24 hr. 11 min., * 0·8 ft., duration 5 hr. 41 min., range 13·3 ft., interval from low water 1 hr. 11 min., $\theta=37°$, height of tide 0·5 ft.

6. High water 05 hr. 36 min. March 6, range 17·6 ft., low water 23 hr. 34 min. March 5, 1·6 ft., duration 06 hr. 02 min., range 16·0 ft., interval from high water 1 hr. 26 min., $\theta=43°$ height of tide 15·4 ft.

7. Standard time 11 hr. 20 min., high water 09 hr. 41 min., 2·9 ft., low water 16 hr. 06 min., 1·3 ft., duration 06 hr. 25 min., range 1·6 ft., interval from high water 01 hr. 39 min., $\theta=46°$, height of tide 2·7 ft.

8. Standard time 14 hr. 50 min., high water 17 hr. 35 min., 10·8 ft., low water 12 hr. 45 min., 3·8 ft., duration 04 hr., 50 min., range 7·0 ft., interval from low water 02 hr. 05 min., $\theta=78°$, height of tide 6·6 ft.

9. High water 19 hr. 41 min., 16·7 ft., low water 13 hr. 47 min., 0·4 ft., duration 05 hr. 54 min., range 17·1 ft., interval from low water 00 hr. 33 min., $\theta=17°$, height of tide 0·0 ft.

10. High water 10 hr. 21 min., 19·4 ft., low water 17 hr. 38 min., 0·7 ft., duration 07 hr. 17 min., range 18·7 ft., interval from high water 00 hr. 29 min., height of tide 19·2 ft. Amount of water above rock 18·2 ft.

11. High water 14 hr. 18 min., 14·3 ft., low water 08 hr. 08 min., 5·2 ft., duration 06 hr. 10 min., range 9·1 ft., interval from high water 00 hr. 58 min., $\theta=28°$, height of tide 13·8 ft. Yes.

12. High water 14 hr. 02 min., 10·9 ft., low water 07 hr. 55 min., 5·3 ft., duration 06 hr. 07 min., range 5·6 ft., correction to L.W. 2·7 ft., $\theta=88°$, required standard time 10 hr. 55 min.

Examples for Practice. Form B.

1.

				Stand. time 03h 00m
Corr. M.S.L. 9·3 ft.	Moon's H.P. 60·8′.			Adj. transit 11h 58m
Line 4.	m 676° M 9·2 ft.	s 027° S 2·8 ft.	k 334° K 0·1 ft.	o 603° O 0·2 ft.
Line 7.	d_m 134°	d_s 063°	d_k 071°	d_o 162°
Line 8.	− 6·4 ft.	+ 1·3 ft.	+ 0·0 ft.	− 0·2 ft.
Height of tide		9·3 − 5·3 = 4·0 ft.		

2.

				Stand. time. 23h 30 m
Corr. M.S.L.	8·0 ft.	Moon's H.P. 59·6′		Adj. transit 05h 00m
Line 4.	m 485° M 7·2 ft.	s 040° S 1·7 ft.	k 368° K 0·3 ft.	o 342° O 0·3 ft.
Line 7.	d_m 220°	d_s 305°	d_k 345°	d_o 11°
Line 8.	−5·6 ft.	+ 1·0 ft.	+ 0·3 ft.	+ 0·3 ft.
Height of tide		8·0 − 4·0 = 4·0 ft.		

3.

				Stand. time 00h 30m
Corr. M.S.L.	2·3 ft.	Moon's H.P. 54·1′		Adj. transit 01h 53m
Line 4.	*m* 275° M 1·9 ft.	*s* 252° S 0·3 ft.	*k* 270° K 0·3 ft.	*o* 358° O 0·1 ft.
Line 7.	d_m 100°	d_s 123°	d_k 098°	d_o 010°
Line 8.	— 0·3 ft.	— 0·2 ft.	— 0·1 ft.	+ 0·1 ft.
Height of tide		2·3 — 0·5 = 1·8 ft.		

4.

				Stand. time 08h 00m
Corr. M.S.L.	13·7 ft.	Moon's H.P. 56·5′		Adj. transit 11h 42m
Line 4.	*m* 496° M 6·7 ft.	*s* 211° S 2·6 ft.	*k* 533° K 2·3 ft.	*o* 822° O 0·9 ft.
Line 7.	d_m 104°	d_s 029°	d_k 307°	d_o 018°
Line 8.	— 1·6 ft.	+ 2·2 ft.	+ 1·4 ft.	+ 0·9 ft.
Height of tide		+ 13·7 + 2·9 = 16·6 ft.		

5.

				Stand. time 23h 00m
Corr. M.S.L.	8·7 ft.	Moon's H.P. 59·2′		Adj. transit 13h 03m
Line 4.	*m* 115° M 6·0 ft.	*s* 136° S 2·0 ft.	*k* 483° K. 0·3 ft.	*o* 213° O 0·4 ft
Line 7.	d_m 215°	d_s 194°	d_k 222	d_o 132°
Line 8.	— 4·9 ft.	— 1·9 ft.	— 0·3 ft.	—0·3 ft.
Height of tide		+ 8·7 — 7·4 = 1·3 ft.		

6.

Corr. M.S.L.	6·5 ft.	Moon's H.P. 54·9′		Stand. time 03h 00m
				Adj. transit 12h 00m
Line 4.	*m* 673° M 4·1 ft.	*s* 016° S 0·9 ft.	*k* 341° K 0·3 ft.	*o* 555° O 0·3 ft.
Line 7.	d_m 137°	d_s 74°	d_k 64°	d_o 210
Line 8.	— 3·0 ft.	+ 0·3 ft.	+ 0·2 ft.	— 0·3 ft.
Height of tide		6·5 — 2·8 = 3·7 ft.		

7.

				Stand. time 12h 00m
Corr. M.S.L.	11·0 ft.	Moon's H.P. 58·9′		Adj. transit 06h 19m
Line 4.	*m* 219° M 9·1 ft.	*s* 101° S 2·6 ft.	*k* 285° K 0·3 ft.	*o* 500° O 0·4 ft.
Line 7.	d_m 141°	d_s 260°	d_k 255°	d_o 40°
Line 8.	— 7·0 ft.	— 0·5 ft.	— 0·1 ft.	+ 0·3 ft.
Height of tide		11·0 — 7·3 = 3·7 ft.		

8.

				Stand. time 03h 00m
Corr. M.S.L.	8·2 ft.	Moon's H.P. 61·2′		Adj. transit 11h 45m
Line 4.	*m* 493° M 7·0 ft.	*s* 220° S 1·9 ft.	*k* 462° K 0·4 ft.	*o* 698° O 0·2 ft
Line 7.	d_m 317°	d_s 230°	d_k 303°	d_o 067°
Line 8.	+ 5·1 ft.	— 1·2 ft.	+ 0·2 ft.	+ 0·1 ft.
Height of tide		8·2 + 4·2 = 12·4 ft.		

Distance off lt.-ho. 1·9 miles.

Note.—Ht. of lt.-ho. is given above M.H.W.S. on chart.

9.

Stand. time Feb. 1, 00·3h

Corr. M.S.L.	3·1 ft.	Moon's H.P. 60·5′	Adj. transit 09h 18m.	
Line 4.	m 452° M 2·1 ft.	s 273° S 0·2 ft.	k 588° K 0·2 ft.	o 520 O 0·1 ft.
Line 7.	d_m 277°	d_s 96°	d_k 137°	d_o 205°
Line 8.	+ 0·3 ft.	+ 0·0 ft.	− 0·1 ft.	− 0·1 ft.
Height of tide		3·1 + 0·1 = 3·2 ft.		

10.

Stand. time 10h 00m

Corr. M.S.L.	1·8 ft.	Moon's H.P. 57·0′	Adj. transit 10h 54m	
Line 4.	m 317° M 0·9 ft.	s 036° S 0·2 ft.	k 218° K 0·3 ft.	o 841 O 0·2 ft.
Line 7.	d_m 343°	d_s 264°	d_k 292°	d_o 29°
Line 8.	+ 0·9 ft.	— ft.	+ 0·2 ft.	+ 0·2 ft.
Height of tide		1·8 + 1·3 = 3·1 ft.		

11.

Stand. time 14h 00m

Corr. M.S.L.	7·0 ft.	Moon's H.P. 56·8′	Adj. transit 05h 37m	
Line 4.	m 228° M 1·2 ft.	s 348° S 1·3 ft.	k 531° K 1·7 ft.	o 367° O 0·9 ft.
Line 7.	d_m 192°	d_s 72°	d_k 039°	d_o 203°
Line 8.	− 1·2 ft.	+ 0·4 ft.	+ 1·3 ft.	− 0·7 ft.
Height of tide		7·0 − 0·2 = 6·8 ft.		
Depth above rock 4·8 ft.				

12.

Stand. time Feb. 17, 22·2h

Corr. M.S.L.	13·7	Moon's H.P. 54·0′	Adj. transit 11h 31m	
Line 4.	m 675° M 8·6 ft.	s 026° S 1·9 ft.	k 453° K 0·4 ft.	o 518° O 0·3 ft.
Line 7.	d_m 351°	d_s 280°	d_k 240°	d_o 175°
Line 8.	+ 8·6 ft.	+ 0·3 ft.	− 0·2 ft.	− 0·3 ft.
Height of tide		13·7 + 8·4 = 22·1 ft.		

13.

Stand. time 20·7h

Corr. M.S.L.	6·6 ft.	Moon's H.P. 57·3′	Adj. transit 05h 58m	
Line 4.	m 183° M 5·3 ft.	s 087° S 1·5 ft.	k160° K 0·1 ft.	o 691° O 0·3 ft.
Line 7.	d_m 78°	d_s 174°	d_k 150°	d_o 339°
Line 8.	+ 1·1 ft.	− 1·5 ft.	− 0·1 ft.	+ 0·3 ft.
Height of tide		6·6 − 0·2 = 6·4 ft.		

14.

Stand. time 20h 12m

Corr. M.S.L.	9·3 ft.	Moon's H.P. 55·8′	Adj. transit 01h 24m	
Line 4.	m 370° M 7·1 ft.	s 022° S 2·8 ft.	k 299° K 0·1 ft.	o 314° O 0·2 ft.
Line 7.	d_m 236°	d_s 224°	d_k 004°	d_o 349°
Line 8.	− 4·0 ft.	− 2·0 ft.	+ 0·1 ft.	+ 0·2 ft.
Height of tide		9·3 − 5·7 = 3·6 ft.		

15.

Stand. time 03h 00m

Corr. M.S.L.	9·7 ft.	Moon's H.P. 55·9′	Adj. transit 06h 17m	
Line 4.	m 317° M 5·5 ft.	s 190° S 1·5 ft.	k 275° K 0·2 ft.	o 728° O 0·2 ft.
Line 7.	d_m 133°	d_s 260°	d_k 130°	d_o 037°
Line 8.	− 3·8 ft.	− 0·3 ft.	− 0·1 ft.	+ 0·2 ft.
Height of tide		9·7 − 4·0 = 5·7 ft.		

16.

			Stand. time 00h 00m	
Corr. M.S.L.	8·0 ft.	Moon's H.P. 54·5′	Adj. transit 00h 35m	
Line 4.	m 163° M 4·2 ft.	s 292° S 1·0 ft.	k 359° K 0·5 ft.	o 432° O 0·4 ft.
Line 7.	d_m 197°	d_s 068°	d_k 001°	d_o 288°
Line 8.	− 4·0 ft.	+ 0·4 ft.	+ 0·5 ft.	+ 0·1 ft.
Height of tide		8·0 − 3·0 = 5·0 ft.		

Examples for Practice. Form A.

1.

Corr. M.S.L. 26·9 ft.	Moon's H.P. 58·0′.	Adj. tran. 02h 22m		
Line 4.	m 086° M 21·6 ft.	s 041° S 3·4 ft.	k 369° K 0·7 ft.	o 340° O 0·6 ft.
Line 7.	f_2 081° F_2 24·5 ft.	f_1 715° F_1 1·3 ft.		
Line 10.	j 21·0 hr.	J 0·0 ft.		
Line 13. Time	08h 42m	14h 42m	20h 42m	02h 42m
Times and heights H. & L. water	2·4 ft.	51·4 ft.	2·4 ft.	51·4 ft.
Line 14. Corr.	− 06m	+ 5m	+ 16m	− 17m
Special accuracy corr. times.	08h 36m	14h 47m	20h 58m	02h 25m
Line 16 Shallow water predictions		None		

2.

Corr. M.S.L. 9·7 ft.	Moon's H.P. 55·3′	Adj. tran. 12h 45m		
Line 4.	m 144° M 5·3 ft.	s 180° S 2·3 ft.	k 370° K 0·1 ft.	o 446° O 0·2 ft.
Line 7.	f_2 515°	F_2 7·1 ft.	f_1 423°	F_1 0·2 ft.
Line 10.	j 23·0 hr.	J nil		
Line 13. Time	11h 12m	17h 12m	23h 12m	5h 12m
Times and heights H. and L. water	2·6 ft.	16·8 ft.	2·6 ft.	16·8 ft.
Line 14. Corr.	− 1m	+ 8m	+ 17m	−10m
Special accuracy corr. times	11h 11m	17h 20m	23h 29m	5h 02m
Line 16. Shallow water predictions	11h 24m 2·4ft.	17h 18m 17·0 ft.	23h 42m 2·4ft.	05h 00m 17·0 ft.

3.

Corr. M.S.L. 11·3 ft.	Moon's H.P. 58·1′	Adj. tran. 08h 06m		
Line 4.	m 395° M 8·0 ft.	s 218° S 2·1 ft.	k 630° K 0·6 ft.	o 374° O 0·5 ft.
Line 7.	f_2 394	F_2 5·9 ft.	f_1 674	F_1 0·7 ft.
Line 10.	j 19·9h	J 0·1 ft.		
Line 13. Time	07h 12m	13 12m	19h 00m	01h 00m
Times and heights H. and L. water	4·8 ft.	16·6 ft.	6·0 ft.	17·8 ft.
Line 14. Corr.	− 13m	+ 3m	+ 19m	− 30m
Special accuracy corr. times	06h 59m	13h 15m	19h 19m	00h 30m
Line 16. Shallow water predictions		None		

4.

Corr. M.S.L. 9·7 ft. Moon's H.P. 61·2′ Adj. trans. 01h 35m
Line 4. *m* 209° M 1·6 ft. *s* 211° S 0·4 ft. *k* 420° K 4·2 ft. *o* 109° O 3·6 ft.
Line 7. f_2 569° F_2 2·0 ft. f_1 444° F_1 7·1ft.
Line 10. *j* 22·6 h J 3·6 ft.

Line 13. Time	15h 30m	—h —m	—h —m	06h 18m
Times and heights H. & L.W.	2·9 ft.	—	—	18·7 ft
Line 14. Corr.	+ 7m	— m	— m	— 12m
Special accuracy corr. times	15h 37m	—h —m	—h —m	06h 06m
Line 16. Shallow water predictions	None			

5.

Corr. M.S.L. 9·3 ft. Moon's H.P. 56·2′ Adj. tran. 01h 54m
Line 4. *m* 384° M 7·3 ft. *s* 022° S 2·8 ft. *k* 297° K 0·1 ft. *o* 329° O 0·2 ft.
Line 7. f_2 023° F_2 10·1 ft. f_1 318° F_1 0·3 ft.
Line 10. *j* 20·4h J nil

Line 13. Time	6h 48m	12h 48m	18h 48m	0h 48m
Times and heights	* 0·8 ft.	19·4 ft.	* 0·8 ft.	19·4 ft.
Line 14. Corr.	— 8m	+ 1 m	+ 11 m	— 17m
Special accuracy corr. times	06h 40m	12h 49m	18h 59m	00h 31m
Line 16. Shallow water predictions	07h 21m *0·8 ft.	12h 27m 19·4 ft.	19h 40 *0·8 ft.	00h 09m 19·4 ft.

6.

Corr. M.S.L. 7·0 ft. Moon's H.P. 57·8′ Adj. tran. 02h 00m
Line 4. *m* 386° M 4·8 ft. *s* 011° S 1·5 ft. *k* 346° K 0·2 ft. *o* 175° O 0·1 ft.
Line 7. f_2 023° F_2 6·2 ft. f_1 337° F_1 0·1 ft.
Line 10. *j* 21·7h J nil.

Line 13. Time	6h 48m	12h 48m	18h 48m	0h 48m
Times and heights H. & L.W.	0·8 ft.	13·2 ft.	0·8 ft.	13·2 ft.
Line 14. Corr	— 7m	+ 1m	+ 10m	— 16m
Special accuracy corr. times	06h 41m	12h 49m	18h 58m	00h 32m
Line 16. Shallow water predictions	05h 28m 0·3 ft.	12h 14m 13·7 ft. 14h 09m 13·6 ft.	17h 45m 0·3 ft	5d 23h 57m 13·7 ft. 01h 52m 13·6 ft.

7.

Corr. M.S.L. 8·7 ft. Moon's H.P. 54·3′ Adj. tran. 11h 24m
Line 4. *m* 427° M 4·6 ft. *s* 132° S 2·0 ft. *k* 315° K 0·2 ft. *o* 699° O 0·3 ft.
Line 7. f_2 086° F_2 5·8 ft. f_1 329° F_1 0·5 ft.
Line 10. *j* 19·1h J 0·1

Line 13. Time	08h 54m	15h 0m	20h 54m	02h 48m
Times and heights H. and L. water	2·3 ft.	14·5 ft.	3·5 ft.	14·5 ft.
Line 14. Corr.	— 5m	+ 5m	+ 15m	— 16m
Special accuracy corr. times	08h 49m	15h 05m	21h 09m	02h 32m
Line 16. Shallow water predictions	None			

8.

Corr. M.S.L. 8·2 ft. Moon's H.P. 61·2′ Adj. tran. 12h 03m

Line 4. *m* 502° M 7·0 ft. *s* 220° S 1·9 ft. *k* 462° K 0·4 ft. *o* 707° O 0·2 ft.

Line 7. f_2 516° F_2 7·6 ft. f_1 792° F_1 0·4 ft.

Line 10. *j* 23·6h J —

Line 13. Time	11h 12m	17h 12m	23h 12m	05h 12m
Times and heights H. and L. water	0·6 ft.	15·8 ft.	0·6 ft.	15·8 ft.
Line 14. Corr.	— 2m	+ 9m	+ 20m	— 12m
Special accuracy corr. times	11h 10m	17h 21m	23h 32m	05h 00m

Line 16. Shallow water
predictions 11h 20m 0·3 ft. 17h 25m 16·1 ft. 23h 42m 0·3 ft. 05h 04m 16·1 ft.

9.

Corr. M.S.L. 13·3 ft. Moon's 59·8′ Adj. tran. 11h 48m

Line 4. *m* 499 M 7·8 ft. *s* 214° S 4·0 ft. *k* 585 K 1·4 ft. *o* 766° O 1·1 ft.

Line 7. f_2 522° F_2 10·0 ft. f_1 940° F_1 0·3 ft.

Line 10. *j* 9·3h J nil

Line 13. Time	05h 24m	11h 24m	17h 24m	23h 24m
Times and heights H. and L. water	23·3 ft.	3·3 ft.	23·3 ft.	3·3 ft.
Line 14. Corr.	— 08m	— 1m	+ 6m	+ 13m
Special accuracy corr. times	05h 16m	11h 23m	17h 30m	23h 37m

Line 16. Shallow water
predictions None

10.

Corr. M.S.L. 9·3 ft. Moon's H.P. 54·8′ Adj. tran. 00h 28m

Line 4. *m* 343° M 6·7 ft. *s* 014° S 2·8 ft. *k* 103 K 0·1 ft. *o* 475° O 0·2 ft.

Line 7. f_2 352° F_2 9·2 f_1 111° F_1 0·3 ft.

Line 10. *j* 19·7h J 0·00 ft.

Line 13. Time	17h 42m	23h 42m	05h 42m	11h 42m
Times and heights H. and L. water	0·1 ft.	18·5 ft.	0·1 ft.	18·5 ft.
Line 14. Corr.	+ 9m	+ 18m	—10m	— 0m
Special accuracy corr. times	17h 51m	24h 00m	05h 32m	11h 42m

Line 16. Shallow water
predictions 18h 32m 0·1 ft. 23h 38m 18·5 ft. 06h 13m 0·1 ft. 11h 20m 18·5 ft.

11.

Corr. M.S.L. 13·3 ft. Moon's H.P. 58.9′ A dj. tran. 06h 19m

Line 4. *m* 341° M 7·5 ft. *s* 215° S 4·1 ft. *k* 597° K 1·2 ft. *o* 602° O 1·0 ft.

Line 7. f_2 308° F_2 6·2 ft. f_1 600° F_1 2·1 ft.

Line 10. *j* 5·7h J 0·3 ft.

Line 13. Time	10h 36m	16h 24m	22h 00m	04h 18m
Times and heights H. and L. water.	20·1 ft.	9·0 ft.	19·5 ft.	5·2 ft.
Line 14. Corr.	— 3m	+ 9m	+ 21m	— 16m
Special accuracy corr. times	10h 33m	16h 33m	22h 21m	04h 02m

Line 16. Shallow water
predictions None

Index, and Glossary of Terms used in connection with Tides.

A°—See page 69.

Admiralty Method—See page 70.

Age of Moon—The number of days, and fraction of a day, that have elapsed since the last conjunction (New Moon).

Age of the Tide—The time interval between conjunction (and opposition) and the appearance of the spring tide due to it. This quantity varies between more than 14 half days (lunar) as a plus value, and 2 half days as a minus value. British tides have an age of about 3 half days (plus). This means that the spring tide will usually be the third tide after conjunction or opposition.

Amphidromic Points—Positions where cotidal lines meet.

Amplitude—The technical name for the distance the crest of a tidal undulation is from mean sea level. It is as often a minus value as plus.

Anomalistic Inequality—Variations in tides due to the variance of the Moon's distance from the Earth.

Apogee—The Moon's position when at her farthest distance from the Earth. Moon's distance when in apogee is about 253,000 miles.

Atlas of Tides and Tidal Streams for the British Isles and Adjacent Waters.—This atlas gives the details of the rate and direction of the tidal stream at one-hour intervals. A chart of co-tidal and co-range lines is included.

Bench Mark—A line cut into some permanent erection to mark a level from which chart datum, etc., can be reckoned.

Bore—A steep tidal wave that forms in some rivers—such as Seine, Severn, Trent—in certain circumstances. It is due to the narrowing of the river and the shoaling of the bottom.

Change of Moon—Another name for "new Moon". Sun and Moon have the same right ascension, and both cross the meridian at 12 hrs. L.A.T.

Chart Datum—The level from which chart soundings are reckoned. It varies in different countries, but is usually somewhere near low water level. Britain uses L.W.O.S.T.* (with exceptions), and an "International Datum"—a sea level, below which the tide very seldom falls—has been suggested, but not generally accepted. The chart datum used in civilized countries is nearly always referred to a land survey datum by means of bench marks and constants. * See page 12.

Co-tidal Lines—Are lines on tidal charts that pass through, either places having the same range of tide or places having the same lunitidal interval.

Component—A term sometimes used to denote that part of the tidal wave due to a harmonic constituent.

Cycle of Meton—Nineteen years are equivalent (nearly) to 235 lunations It follows that the dates of new and full Moon will repeat themselves every 19 years. This period is called the "cycle of Meton", or "metonic cycle".

Declination Inequalities—Variation in the tidal heights, or times of high water, due to the declinations of the Sun and Moon.

Diurnal—Occurring once in a tidal day.

Drift—The distance a particle of water in a tidal current travels in a given time. It equals rate × time.

Duration—Is the time interval between low water and following high water; or between high water and following low water.

Differences—The differences between times and heights of high or low waters at one position and the times and heights of high or low waters at another position.

Ebb—The vertical falling of sea level due to tide.

Ebb Stream—The lateral movement of the water due to the ebb of the tide. This term should not be used unless the movement is actually due to this cause.

Epact—The difference in days and fractions of a day between 12 lunations and the civil year. The average amount is about 10 days 15 hours (11 days 15 hours in leap years), and there will thus be this difference in the Moon's age at 00 hours on January 1 in successive years. The epact of the year is the Moon's age at 00 hours on January 1.

Equinoctial Tides—Are tides of unusual height occurring about the time of the equinoxes.

Establishment of the Port—Another name for the lunitidal interval. See par. 11.

Flood—The vertical rising of sea level due to tide.

Flood Stream—The lateral movement of the water due to the flooding (or flowing) of the tide. This term should not be used unless the movement is actually due to this cause.

Harmonic Method—See page 67.

High Water—The highest level of any individual tide.

H.W.F.&C.—High water at full and change of Moon. See page 8.

Height—The height of a tide is the distance that water level is above chart datum.

Horizontal Parallax—For tidal purposes we consider this as an angle at the centre of the Moon that is subtended by the Earth's radius. It is therefore an indication of the Moon's distance from the Earth, and consequently is connected with the Moon's pull on the waters of the Earth.

K_1—An harmonic constituent that, working in conjunction with O_1, represents the diurnal factors of the tide that are due to the Moon's declination. These K_1 O_1 combine when declination is maximum, but neutralise one another when declination is 0°.

Lagging—The lateness of the tide. See page 6.

Low Water—The lowest level reached by any individual tide.

Lunation—The period of time taken by the Moon to go through all her phases from new Moon to new Moon: in conjunction to conjunction. Its average value is 29d. 12 hrs. 44 min. 2·87 sec.

Lunitidal Interval—The interval between the time of Moon's transit and the following high water. It is also applied to the transit of new or full Moon; in which case it is the same as H.W.F.&C.

Mean Sea Level—The level above which the tide rises and falls by approximately equal amounts. It is not exactly the same as mean tide level, but is never

more than 9 inches different from it. It may vary in different years, or even in different months.

Methods of Predicting Tides in their Order of Accuracy.—

1. The Harmonic method.
2. The Admiralty method.
3. Tidal differences and ratios.
4. The co-tidal chart of the British Isles and adjacent waters, for places in the open sea in the vicinity of the British Isles.
5. Non-harmonic constants given on the chart.

Mixed Tides—Those in which the diurnal and semi-diurnal features are both operating, and causing rather complex series of times and heights.

M.T.L.—Mean tide level. See page 11.

M.S.L.—Mean sea level.

M.S.R.—Mean spring rise.

M.N.R.—Mean neap rise.

M.H.W.I.—Mean lunitidal interval of high waters.

M.L.W.I.—Mean lunitidal interval of low waters.

M.H.H.W.—Mean higher high water. The mean of the higher of the high waters in mixed tides.

M.L.L.W.—Mean lower low water. The mean of the lower of the low waters in mixed tides.

M_o—The distance between chart datum and mean tide level.

M_2—Harmonic constituent representing the tidal effect of the Moon at a mean distance from the Earth and travelling at a constant speed with a declination of 0°.

Neap Tides—Tides having the lowest high water and the highest low water. Occurring near time of Moon's quadrature.

Non Harmonic—Applied to constants and methods that do not involve the separation and separate calculation of the numerous factors acting in the tide.

Non-Periodic Meteorological Phenomena.—The tides are affected by the changes in the force and direction of the wind, and the height of the barometer. No absolute rule can be given, the effects being continental rather than local in effect; for example, strong east winds over Northern Europe are "on shore" winds on the East Coast of England and "off shore" wind to Europe generally, the general effect being to lower the height of mean level in the North Sea.

Opposition—The position of the Moon when it is on the opposite side of the Earth to the Sun. It's R.A. is therefore 12 hours different from that of the Sun.

O_1—Harmonic constituents. See K_1.

Over Tides—Sometimes called quarter diurnal tides. They are nearly always due to the shoaling of the water, but may also be due to a narrowing of the channel. If a tidal undulation passes over shoals or through narrow channels a certain amount of the wave will be slowed up. It will arrive later, however, and may manifest itself as a partial rise after the main tide has begun to fall.

Perigee—The position of the Moon when she is nearest to the Earth. Her distance is then about 221,600 miles.

Priming—The earliness of the high water. See par. 6.

Phases—The Moon's appearances, waxing from new to full and then waning to new again.

Quadrature—The Moon's position when at a right ascension 6 hours different from that of the Sun. It must therefore be half way between conjunction and opposition or opposition and conjunction.

Quarter Diurnal Tides—Tides that manifest themselves four times daily. Part of them appear about the time of high water, and the other part follows later. The latter part is an "over tide."

R—See page 55.

Range—The difference in height between high or low water and the succeeding low or high water respectively.

Ratio—

Ratio of Ranges is the ratio of the range of the tide at a Secondary port to the range at a Standard port. The height of the tide above or below mean sea-level at Standard port multiplied by the ratio of ranges gives the height of the tide above or below mean sea-level at the Secondary port.

Ratio of Rises.—Is the ratio which the rise of the tide at a Secondary port bears to the rise of the tide at a Standard port. The relation between the rise at springs and the rise at neaps is not the same at all places. Where only one is known, neap rise can be taken to be spring rise multiplied by 0·8.

Rise—The distance between high water level and chart datum.

Retard of the Tide—Another name for the "age of the tide".

Saros—Nineteen revolutions of the Sun with respect to the nodes of the Moon is equal in time to 223 lunations. This time, which equals 18 years 11 days is called the "saros". At one time it was used in tidal work but is now practically obsolete.

Satellite—The harmonic constituents are sometimes termed satellites.

Seasonal Corrections—Adjustments to be applied to the height of mean sea level when this changes during the course of a year.

Secondary Ports—Those whose tidal differences are based on a specified port known as the "Standard port".

Seiches—Oscillations of the water that cause a fluctuation in water level, but are not due to tidal forces. They may affect the tidal undulation by making its outline "serrated" or saw-toothed. The chief causes of seiches are wind and variations of barometric pressure. The "seiche" effect of wind is very marked in some ports, *e.g.* Wilhelmshaven. Fluctuations in the water level of great lakes and inland seas are seiches, and not tides.

Semimenstrual Inequalities—Inequalities in the tide that occur twice during a lunation.

Shallow Water Corrections—Quantities to be applied to a tidal prediction to correct for the "quarter diurnal tides". They are ascribed to the M_4 and MS_4 constituents.

Single Day Tides.—At certain places the form of the composite tide wave will be diurnal, and when this occurs there may be only one high and one low water a day. These are known as SINGLE DAY TIDES.

Slack Water.—The period when the tide ceases to move laterally, irrespective of its vertical movement. It must not be confused with "stand of tide".

Solstitial Tides.—Tides occurring about the time of the solstices. Due to the Sun and Moon having large declinations these tides are usually smaller in height than the average.

Stand of Tide—That period at which the tide ceases to rise or fall, vertically.

Standard Port—A selected port for which daily tidal predictions are tabulated, and which form a basis for computing tides at other (Secondary) ports.

Syzygy—A term used to mean that the Sun, Moon and Earth are in line. It is a handy way of expressing "opposition and/or conjunction".

Tidal Stream—A current in the sea that is wholly dependent on tide, and undergoes change of speed and direction at different states of the tide. These conditions distinguish it from a "current". It is mainly caused by restrictions imposed on the free translation of the tidal wave by the narrowing of the channel or variations of its depth.

Tidal Stream Arrows.—The practice of using arrows to show tidal information was discontinued in 1933. On certain charts, however. arrows are still used when information suitable for the present tabular form is not available. These arrows are referred to on Chart 5011.

Tide and Half Tide—Applied to tidal streams that change or reverse their directions about the time of half flood and half ebb of the tidal undulations.

Tropic Tides—A term sometimes used to denote diurnal tides. Actually it refers to the "trope" or "turning" of the Sun and Moon in declination, but as these tides largely prevail in the tropics it has a certain appropriateness.

U—See page 55.

Undulations—A complete tidal wave, from the trough of the low water before the crest of the high water to the trough of the low water after it. If we cut a vertical section through the sea at any moment we should find that its surface was a series of undulations.

Z_0—A symbol used in A.T.T. II (1938), and is the "Admiralty method" equivalent for the "Harmonic" A_0.

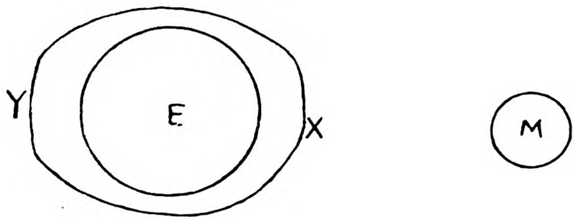
APPENDIX.

Explanation of why the Moon's Attraction Causes Two Tides 180° apart.

The gravitational attraction between the Earth and Moon would draw these bodies together if it were not for the centrifugal force set up by the Moon's revolution around the Earth. This centrifugal force of withdrawal is exactly balanced by the gravitational forces between the two bodies.

The rotation of the Earth on its axis sets up centrifugal forces of withdrawal in the waters of the Earth, but these are dominated by the attraction towards the Earth's centre of gravity.

It is well known that gravitational forces between two bodies vary directly with their masses, and inversely as the square of the distance between them.



In the diagram, there are gravitational forces exerted towards E and towards M. A particle of water at X is being attracted towards E by Earth's gravity, and towards M by Moon's gravity. If we assume distance E M to be 224,000 miles, and distance E X, E Y to be 4000 miles, then the attraction of M on E, Y and X is relatively as $224{,}000^2$, $220{,}000^2$, $228{,}000^2$. Let us represent the gravitional pull of E as $224{,}000^2 = 50176 \times 10^6$.

(We will exclude the common factor 10^6 from the following values.)

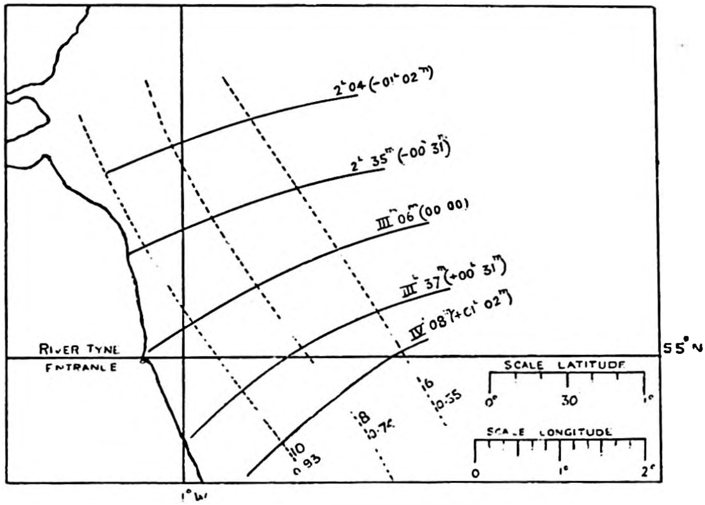
A particle of water at X is attracted towards E by a force of 50176; it tends to move away from E by a centrifugal force F, and it is attracted towards M by an increase of M expressed by $228{,}000^2 - 224{,}000^2 = 1808$. Suppose the resultant of these forces sets up a tide of 18·08 feet.

A particle of water at Y is attracted towards E by a force of 50176 ; it tends to move away from E (and M) by a centrifugal force F, and its attraction towards M is diminished by a decrease expressed by $224{,}000^2 - 220{,}000^2 = 1776$. This decrease in the Moon's pull is approximately equal to the increase of the Moon's pull at X, and would then, theoretically, cause a tide of 17·76 feet to form at Y.

This can be looked upon as if the centrifugal force F has been increased by an amount equal to the diminished pull of the Moon. To express it differently, the water at X is above mean level because the Moon's attraction is 1808 units greater than it is

at E. The water at Y is above sea level because the Moon's attraction is 1776 units less than it is at E. One tide is being pulled up from mean level because it is under the Moon's maximum pull; one tide is tending to move away from E because it is under the Moon's minimum pull.

Tidal Atlas Predictions.



Required times and heights of high and low waters P.M., 29th January, 1939.

Ship's position Lat. 56° 00′ N., Long. 0° 35′ W.

	H.W.		L.W.	
1. River Tyne A.T.T. I - - -	21h 30m	11·4 ft.	15h 01m	3·7 ft.
From chart - - - - - -	—00 31	× ·70	—00 31	× ·70
Predicted tides - - - - -	20 59	8·0	14 30	2·6

2. Required times and heights of high and low waters A.M. 10th February, 1939.

Ship's position Lat. 55° 30′ N., Long. 0° 31′ E.

	H.W.		L.W.	
River Tyne - - - - -	07h 35m	12·9 ft.	01h 26m	1·2 ft.
From chart - - - - - -	+00 15	× ·65	+00 15	× ·65
Predicted tides - - - - -	07 50	8·4	01 45	0·8

3. Required times and heights of high and low waters P.M., 13th January, 1939.

Ship's position Lat. 55° 30′ N., Long. 0° 31′ E.

Eight days after full Moon = 6 days after spring tides.

Moon's transit (*N.A.*) -	18h 50m		Mean range (chart) -	7·0 ft.
H.W. int. (chart) -	+ 3 21		Constant - - -	× 1·3
Time of high water - -	22 11		Spring rise - - -	9·1
Duration of rise - -	6 12		Neap ,, - - -	7·0
Time of L.W. (previous) -	15 59		Difference - - -	2·1
				× $\frac{6}{7}$
			$\frac{6}{7}$ of difference - -	1·8
			Spring rise - - -	9·1
			Height of H.W. - -	7·3
			Height of L.W. - -	1·8

Notes to Example 3.—Assume spring tides occur about two days after full or change of the Moon. Time of H.W. = Moon's transit + H.W. interval.

Duration of rise or fall is $\frac{1}{4}$ lunar day, say 6h 12m.

Assume mean range = neap rise; and spring rise = neap rise × 1·3 (a constant).

Assume seven days from springs to neaps.

The height of H.W. is 1·8 ft. less than at springs (9·1 ft.) so that the height of L.W. is 1·8 more than at springs (0·0 ft. chart datum).

4. Required times and heights of high and low water A.M., 6th February, 1939. Lat. 56° 00′ N., Long. 0° 35′ W.

Two days after full Moon—spring tides.

Moon's transit (*N.A.*) - -	1h 42m		Mean range - - -	7·8 ft.
High water interval - -	2 35			× 1·3
Time of high water - -	4 17		Spring rise - - -	10·1 = H.W.
Duration of fall -	+ 6 12			00·0 L.W.
Time of L.W. (subsequent)	10 29			

APPENDIX.

ADMIRALTY TIDE TABLES—Parts Ia and Ib.

DEVONPORT, 1939 Lat. 50° 22′ N., Long. 4° 11′ W.

JANUARY

Month Day	Week Day	High Water Time H. M.	High Water Ht. F.	Low Water Time H. M.	Low Water Ht. F.
1	**S.**	0030	12·3	0640	4·9
		1300	12·6	1920	4·2
2	M.	0143	12·7	0758	4·3
		1416	13·1	2036	3·2
3	Tu.	0257	13·5	0915	3·1
		1529	13·5	2149	2·3
4	W.	0401	14·4	1017	2·0
		1630	14·4	2249	1·4
5	Th.	0457	15·3	1117	1·0
		1724	15·4	2344	0·8
6	F.	0547	16·4	—	—
		1815	16·3	1208	0·4
7	S.	0638	17·1	0033	0·5
		1904	16·8	1258	0·1
8	**S.**	0723	17·1	0122	0·2
		1952	16·6	1347	*0·1
9	M.	0807	17·0	0208	0·5
		2038	16·0	1433	0·3
10	Tu.	0853	16·7	0252	1·2
		2123	15·5	1517	1·3
11	W.	0939	15·9	0335	1·8
		2203	14·6	1559	2·1
12	Th.	1025	14·9	0416	2·8
		2250	13·7	1646	3·3

FEBRUARY

Month Day	Week Day	High Water Time H. M.	High Water Ht. F.	Low Water Time H. M.	Low Water Ht. F.
3	F.	0142	14·9	1103	1·0
		1714	14·8	2329	0·4
4	S.	0534	15·9	1153	*0·4
		1802	15·7	—	—
5	**S.**	0626	16·6	0022	*0·5
		1849	16·2	1243	*1·1
11	S.	1036	13·8	0429	3·4
		2259	12·9	1651	4·0
12	**S.**	1124	12·5	0513	4·6
		—	—	1740	5·0
13	M.	0002	12·3	0624	5·2
		1237	11·6	1856	5·5

MARCH

Month Day	Week Day	High Water Time H. M.	High Water Ht. F.	Low Water Time H. M.	Low Water Ht. F.
4	S.	0426	14·6	1048	0·3
		1700	14·5	2317	0·1
5	**S.**	0523	15·5	1139	*0·8
		1749	15·3	—	—
6	M	0611	16·4	0009	*1·0
		1834	15·8	1231	*1·6
7	Tu.	0659	16·6	0056	*1·4
		1914	16·3	1318	*1·8
8	W.	0738	16·5	0137	*1·5
		1952	16·2	1358	*1·3
9	Th.	0811	16·1	0215	*0·8
		2030	15·4	1433	*0·5

APRIL

Month Day	Week Day	High Water Time H. M.	High Water Ht. F.	Low Water Time H. M.	Low Water Ht. F.
8	S.	0823	14·8	0228	0·4
		2034	14·5	1437	0·8
9	**S.**	0858	14·0	0258	1·4
		2107	14·0	1507	1·9
10	M.	0929	13·3	0326	2·8
		2143	13·1	1538	3·5
13	Th.	—	—	0620	4·9
		1237	11·3	1851	5·2
14	F.	0112	12·0	0740	4·6
		1347	11·6	2008	4·6
15	S.	0226	12·5	0846	3·8
		1456	12·7	2115	3·9
16	**S.**	0325	13·3	0943	2·9
		1547	13·2	2202	2·7

PORTSMOUTH, 1939 Lat. 50° 48′ N., Long. 1° 07′ W.

JANUARY

26	Th.	0226	12·3	0731	1·8
		1433	11·9	1940	1·7
27	F.	0302	12·0	0805	2·2
		1512	11·5	2019	2·2
28	S.	0345	11·6	0850	2·9
		1600	11·0	2110	3·0

FEBRUARY

3	F.	1020	13·1	0317	0·7
		2251	13·3	1542	*0·1
4	S.	1109	13·7	0408	*0·2
		2343	14·0	1630	*1·2
5	**S.**	—	—	0456	*0·9
		1202	14·1	1717	*1·8

MARCH

13	M.	0438	1[illegible]·5	0943	3·4
		1719	10·0	2221	4·0
14	Tu.	0548	9·9	1107	4·1
		1843	9·7	2351	4·2
15	W.	0714	9·7	—	—
		2004	10·1	1237	3·8

DOVER, 1939 Lat. 51° 07′ N., Long. 1° 19′ E.

MAY

17	W.	0956	17·1	0449	1·4
		2206	17·8	1708	1·2
18	Th.	1030	17·8	0532	0·7
		2244	18·4	1747	0·6
19	F.	1105	18·5	0611	0·2
		2323	18·5	1827	*0·1
20	S.	1140	18·6	0651	0·0
		—	—	1909	*0·4
21	**S.**	0003	18·4	0733	*0·2
		1223	18·4	1949	*0·4
22	M.	0047	18·4	0813	*0·2
		1307	18·3	2030	*0·2
23	Tu.	0136	18·1	0856	0·3
		1356	18·3	2121	0·0
24	W.	0225	17·4	0942	0·7
		1446	17·8	2211	0·6
25	Th.	0319	16·7	1033	1·6
		1545	16·9	2307	1·4
26	F.	0424	16·0	1135	2·3
		1651	16·5	—	—

JUNE

19	M.	—	—	0721	*0·3
		1214	18·8	1946	*0·8
20	Tu.	0038	18·5	0806	*0·3
		1259	19·0	2031	*0·6
21	W.	0125	18·5	0850	0·1
		1347	18·8	2118	*0·3
22	Th.	0216	17·9	0936	0·6
		1437	18·5	2206	0·2
23	F.	0308	17·5	1025	1·0
		1529	18·0	2256	1·0
24	S.	0404	16·8	1118	1·9
		1627	17·3	2352	1·7
25	**S**	0508	16·1	—	—
		1733	16·5	1214	2·6
26	M.	0616	15·6	0058	2·3
		1845	16·1	1320	3·0

JULY

22	S.	0250	18·0	1009	0·7
		1508	18·8	2238	0·7
23	**S.**	0342	17·3	1051	1·6
		1601	17·6	2323	1·7
24	M.	0437	16·3	1139	2·6
		1704	16·6	—	—

Time meridian Greenwich (Zone 0): 00h is midnight, 12h is noon. Heights are referred to the datum of the largest scale Admiralty chart of the place and should be *added* to depths, unless preceded by an asterisk (*) when they should be *subtracted*. To find height at times between high and low water *see* pages 106-107.

ADMIRALTY TIDE TABLES—Parts Ia and Ib.—contd.

LONDON BRIDGE, 1939 Lat. 51° 30′ N., Long. 0° 05′ W.

Month Day	Week Day	MAY				Month Day	Week Day	JUNE				Month Day	Week Day	JULY				Month Day	Week Day	AUGUST			
		High Water		Low Water				High Water		Low Water				High Water		Low Water				High Water		Low Water	
		Time H. M.	Ht. F.	Time H. M.	Ht. F.			Time H. M.	Ht. F.	Time H. M.	Ht. F.			Time H. M.	Ht. F.	Time H. M.	Ht. F.			Time H. M.	Ht. F.	Time H. M.	Ht. F.
5	F.	0247	22·3	0948	0·3	7	W.	0503	20·4	1112	2·1	5	W.	0407	21·0	1028	1·8						
		1503	22·5	2203	0·3			1702	20·3	2352	1·2			1611	21·6	2254	0·7						
6	S.	0324	22·4	1018	0·9	8	Th.	0542	19·8	1144	2·3	6	Th.	0445	20·6	1102	1·7						
		1539	22·3	2230	0·7			1742	19·7	—	—			1643	21·2	2327	0·8						
7	**S.**	0403	21·9	1044	1·2	9	F.	0626	18·9	0005	1·3	7	F.	0520	20·1	1134	1·7						
		1614	21·8	2253	1·1			1826	19·4	1217	2·3			1719	20·5	2357	1·1						

RIVER TYNE, 1939

Lat. 55° 01′ N., Long. 1° 24′ W.

(PORT OF BRISTOL) KING ROAD, 1939

Lat. 51° 30′ N., Long. 2° 43′ W.

JANUARY						FEBRUARY						FEBRUARY						NOVEMBER					
13	F.	0905	12·1	0251	2·3	10	F.	0735	12·9	0126	1·2	5	**S.**	0754	44·8	0243	*0·5	19	**S.**	—	—	0 46	10·4
		2137	11·9	1516	3·5			1955	13·1	1337	2·5			2020	44·7	1514	*0·8			1201	31·5	1826	10·1
29	**S.**	0905	11·1	0242	3·2							6	M.	0840	45·5	0331	*1·1	20	M.	0037	30·1	0647	12·5
		2130	11·4	1501	3·7									2101	45·0	1557	*1·0			1312	30·5	1940	11·6
												7	Tu.	0921	45·5	0411	*0·9	21	Tu.	0155	30·1	0812	11·9
														2146	44·3	1635	*0·5			1436	31·1	2103	11·0
																		28	Tu.	0746	42·0	0214	1·7
																				2011	41·6	1447	2·2
																		29	W.	0827	41·9	0255	1·7
																				2053	41·2	1530	2·0
																		0	Th.	0909	41·4	0346	2·0
																				2137	40·4	1608	2·5

Time meridian Greenwich (Zone 0); 00h is midnight, 12h is noon.

ADMIRALTY TIDE TABLES—Parts Ia and Ib.—contd.

HELGOLAND, 1939 Lat. 54° 11′ N., Long. 7° 54′ E.

JANUARY					
5	Th.	1105	8·1	0524	0·3
		2328	8·8	1751	0·4
6	F.	—	—	0518	0·0
		1205	8·3	1840	0·4
7	S.	0023	9·3	0705	0·1
		1254	8·6	1928	0·4
10	Tu.	0243	9·4	0931	*0·3
		1519	8·2	2147	0·2
11	W.	0328	8·9	1012	*0·3
		1603	7·8	2227	0·3
12	Th.	0413	8·5	1054	0·3
		1647	7·5	2313	0·9

FEBRUARY					
9	Th.	0309	8·8	0951	*0·7
		1537	7·9	2205	0·1
10	F.	0350	8·3	1027	0·2
		1616	7·7	2247	0·4
11	S.	0432	7·9	1111	0·2
		1651	7·5	2336	0·5
12	S.	0514	7·5	1159	0·4
		1743	7·4	—	—
13	M.	0613	7·2	0033	0·5
		1847	7·4	1301	0·6

MARCH					
1	W.	0632	7·1	0049	0·4
		1907	7·6	1327	1·0
2	Th.	0803	7·0	0211	0·8
		2033	7·7	1453	1·2
3	F.	0923	7·1	0337	0·8
		2146	8·2	1610	1·0

APRIL					
9	S.	0257	8·0	0936	*0·1
		1511	8·1	2157	0·0
10	M.	0337	7·6	1009	0·4
		1548	8·0	2234	0·6
11	Tu.	0419	7·3	1048	0·8
		1629	7·8	2316	0·6

Time meridian Greenwich (Zone −1) 00h is midnight, 12h is noon.

KEM, 1939

Lat. 64° 59′ N., Long. 34° 59′ N.

JANUARY					
1	S.	—	—	0620	2·5
		1204	5·1	1852	1·8
2	M.	0052	5·3	0730	2·1
		1303	5·2	1954	1·6
3	Tu.	0145	5·5	0828	1·9
		1353	5·4	2046	1·4
4	W.	0232	5·7	0920	1·6
		1444	5·5	2135	1·2

Time meridian 30° E (Zone −2)

SIERRA LEONE, 1939

Lat. 8° 30′ N., Long. 13° 14′ W.

SEPTEMBER					
6	W.	1109	8·1	0510	3·3
		2356	8·0	1736	3·1
7	Th.	—	—	0619	3·6
		1226	7·8	1851	3·4
8	F.	0120	8·0	0740	3·6
		1355	7·9	2014	3·2
13	W.	0632	11·0	0021	0·8
		1856	10·7	1250	0·5
14	Th.	0716	11·2	0110	0·5
		1941	10·9	1336	0·3
15	F.	0800	11·1	0155	0·4
		2025	10·6	1420	0·4

Time meridian 15° W (Zone +1)

HOOK OF HOLLAND, 1939

Lat. 51° 59′ N., 4° 07′ E.

APRIL		H.W.			L.W.		L.W.
22	S.	0318	6·3	0347	0·3	1129	0·3
		1611	6·5	2106	0·8	2331	0·5
23	S.	0428	6·5	0929	0·5	—	—
		1654	6·3	2148	0·8	1206	0·5
24	M.	0506	6·4	—	—	0018	0·6
		1733	6·0	2232	0·8	1155	0·3
29	S.	1040	6·7	—	—	0526	0·6
		2324	6·0	1617	1·4	1849	1·4
30	S.	1142	6·9	0423	0·6	0717	0·9
		—	—	1708	1·5	1952	1·3

N.B.—Hook of Holland has *two* Low Waters.

Time meridian 4° 53′ E (00h 20m fast)

ADMIRALTY TIDE TABLES.—Part I.

TABLE 1 (*a*).—θ. Intervals from High or Low Water in Angle.

Duration of Rise or Fall		Interval from High or Low Water. 0 hour					1 hour						2 hours						3 hours						4h.	Duration of Rise or Fall	
		10ᵐ	20ᵐ	30ᵐ	40ᵐ	50ᵐ	00ᵐ	10ᵐ	20ᵐ	30ᵐ	40ᵐ	50ᵐ	00ᵐ	10ᵐ	20ᵐ	30ᵐ	40ᵐ	50ᵐ	00ᵐ	10ᵐ	20ᵐ	30ᵐ	40ᵐ	50ᵐ	00ᵐ		
H.	M.	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	H.	M.
3	30	09	17	26	34	43	52	60	68	77	86	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	30
	40	08	16	25	33	41	49	57	65	74	82	90	—	—	—	—	—	—	—	—	—	—	—	—	—		40
	50	08	16	23	31	39	47	55	63	70	78	86	—	—	—	—	—	—	—	—	—	—	—	—	—		50
4	00	07	15	22	30	37	45	52	60	67	75	82	90	—	—	—	—	—	—	—	—	—	—	—	—	4	00
	10	07	14	22	29	36	43	50	58	65	72	79	86	—	—	—	—	—	—	—	—	—	—	—	—		10
	20	07	14	21	28	35	42	48	55	62	69	76	83	90	—	—	—	—	—	—	—	—	—	—	—		20
	30	07	13	20	27	33	40	47	53	60	67	73	80	87	—	—	—	—	—	—	—	—	—	—	—		30
	40	06	13	19	26	32	39	45	51	58	64	71	77	84	90	—	—	—	—	—	—	—	—	—	—		40
	50	06	12	19	25	31	37	43	50	56	62	68	74	81	87	—	—	—	—	—	—	—	—	—	—		50
5	00	06	12	18	24	30	36	42	48	54	60	66	72	78	84	90	—	—	—	—	—	—	—	—	—	5	00
	10	06	12	17	23	29	35	41	46	52	58	64	70	75	81	87	—	—	—	—	—	—	—	—	—		10
	20	06	11	17	22	28	34	40	45	51	56	62	68	73	79	84	90	—	—	—	—	—	—	—	—		20
	30	05	11	16	22	27	33	38	44	49	55	60	65	71	76	82	87	—	—	—	—	—	—	—	—		30
	40	05	11	16	21	26	32	37	42	48	53	58	63	69	74	79	85	90	—	—	—	—	—	—	—		40
	50	05	10	15	21	26	31	36	41	46	51	56	62	67	72	77	82	87	—	—	—	—	—	—	—		50
6	00	05	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	—	—	—	—	—	—	6	00
	10	05	10	15	19	24	29	34	39	44	49	54	58	63	68	73	78	83	87	—	—	—	—	—	—		10
	20	05	09	14	19	24	28	33	38	43	47	52	57	62	66	71	76	81	85	90	—	—	—	—	—		20
	30	05	09	14	18	23	28	32	37	42	46	51	55	60	65	69	74	78	83	88	—	—	—	—	—		30
	40	04	09	13	18	22	27	31	36	40	45	49	54	58	63	67	72	76	81	85	90	—	—	—	—		40
	50	04	09	13	18	22	26	31	35	40	44	48	53	57	61	66	70	75	79	83	88	—	—	—	—		50
7	00	04	09	13	17	21	26	30	34	39	43	47	51	56	60	64	69	73	77	81	86	90	—	—	—	7	00
	10	04	08	13	17	21	25	29	33	38	42	46	50	54	59	63	67	71	75	80	84	88	—	—	—		10
	20	04	08	12	16	20	25	29	33	37	41	45	49	53	57	61	65	70	74	78	82	86	90	—	—		20
	30	04	08	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80	84	88	—	—		30
	40	04	08	12	16	20	23	27	31	35	39	43	47	51	55	59	63	67	70	74	78	82	86	90	—		40
	50	04	08	11	15	19	23	27	31	34	38	42	46	50	54	57	61	65	69	73	77	80	84	88	—		50
8	00	04	07	11	15	19	22	26	30	34	37	41	45	49	52	56	60	64	67	71	75	79	82	86	90	8	00

TABLE I (*b*).—Corrections to Heights of High or Low Water.

Range	5		6		7		8		9		10		11		12		13		14		15		16		17		18		19		20	Range
θ °	0·0	0·5	0·0	0·5	0·0	0·5	0·0	0·5	0·0	0·5	0·0	0·5	0·0	0·5	0·0	0·5	0·0	0·5	0·0	0·5	0·0	0·5	0·0	0·5	0·0	0·5	0·0	0·5	0·0	0·5	0·0	θ °
00	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	00
10	0·0	0·0	0·0	0·0	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·2	10
15	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·2	0·2	0·2	0·2	0·2	0·2	0·2	0·2	0·2	0·2	0·2	0·3	0·3	0·3	0·3	0·3	0·3	0·3	0·3	0·3	0·3	0·3	15
20	0·2	0·2	0·2	0·2	0·2	0·2	0·2	0·3	0·3	0·3	0·3	0·3	0·3	0·3	0·4	0·4	0·4	0·4	0·4	0·4	0·5	0·5	0·5	0·5	0·5	0·5	0·5	0·6	0·6	0·6	0·6	20
25	0·2	0·3	0·3	0·3	0·3	0·4	0·4	0·4	0·4	0·4	0·5	0·5	0·5	0·5	0·6	0·6	0·6	0·6	0·7	0·7	0·7	0·7	0·7	0·8	0·8	0·8	0·8	0·9	0·9	0·9	0·9	25
30	0·3	0·4	0·4	0·4	0·5	0·5	0·5	0·6	0·6	0·6	0·7	0·7	0·7	0·8	0·8	0·8	0·9	0·9	0·9	1·0	1·0	1·0	1·1	1·1	1·1	1·2	1·2	1·2	1·3	1·3	1·3	30
32	0·4	0·4	0·5	0·5	0·5	0·6	0·6	0·6	0·7	0·7	0·8	0·8	0·8	0·9	0·9	1·0	1·0	1·0	1·1	1·1	1·1	1·2	1·2	1·3	1·3	1·3	1·4	1·4	1·4	1·5	1·5	32
34	0·4	0·5	0·5	0·6	0·6	0·6	0·7	0·7	0·8	0·8	0·9	0·9	0·9	1·0	1·0	1·1	1·1	1·2	1·2	1·2	1·3	1·3	1·4	1·4	1·5	1·5	1·5	1·6	1·6	1·7	1·7	34
36	0·5	0·5	0·6	0·6	0·7	0·7	0·8	0·8	0·9	0·9	1·0	1·0	1·1	1·1	1·1	1·2	1·2	1·3	1·3	1·4	1·4	1·5	1·5	1·6	1·6	1·7	1·7	1·8	1·8	1·9	1·9	36
38	0·5	0·6	0·6	0·7	0·7	0·8	0·8	0·9	1·0	1·0	1·1	1·1	1·2	1·2	1·3	1·3	1·4	1·4	1·5	1·5	1·6	1·6	1·7	1·7	1·8	1·9	1·9	2·0	2·0	2·1	2·1	38
40	0·6	0·6	0·7	0·8	0·8	0·9	0·9	1·0	1·1	1·1	1·2	1·2	1·3	1·3	1·4	1·5	1·5	1·6	1·6	1·7	1·8	1·8	1·9	1·9	2·0	2·0	2·1	2·2	2·2	2·3	2·3	40
42	0·6	0·7	0·8	0·8	0·9	1·0	1·0	1·1	1·2	1·2	1·3	1·3	1·4	1·5	1·5	1·6	1·7	1·7	1·8	1·9	1·9	2·0	2·1	2·1	2·2	2·2	2·3	2·4	2·4	2·5	2·6	42
44	0·7	0·8	0·8	0·9	1·0	1·1	1·1	1·2	1·3	1·3	1·4	1·4	1·5	1·6	1·7	1·8	1·8	1·9	2·0	2·0	2·1	2·2	2·2	2·3	2·4	2·5	2·5	2·6	2·7	2·7	2·8	44
46	0·8	0·8	0·9	1·0	1·1	1·2	1·2	1·3	1·4	1·4	1·5	1·6	1·7	1·7	1·8	1·9	2·0	2·0	2·1	2·2	2·3	2·3	2·4	2·5	2·6	2·6	2·7	2·8	2·9	2·9	3·1	46
48	0·8	0·9	1·0	1·1	1·2	1·2	1·3	1·4	1·5	1·6	1·7	1·7	1·8	1·9	2·0	2·1	2·2	2·2	2·3	2·4	2·5	2·6	2·6	2·7	2·8	2·9	3·0	3·1	3·1	3·2	3·3	48
50	0·9	1·0	1·1	1·2	1·3	1·3	1·4	1·5	1·6	1·7	1·8	1·9	2·0	2·1	2·1	2·2	2·3	2·4	2·5	2·6	2·7	2·8	2·9	3·0	3·0	3·1	3·2	3·3	3·4	3·5	3·6	50
52	1·0	1·1	1·2	1·2	1·3	1·4	1·5	1·6	1·7	1·8	1·9	2·0	2·1	2·2	2·3	2·4	2·5	2·6	2·7	2·8	2·9	3·0	3·1	3·2	3·3	3·4	3·5	3·6	3·6	3·7	3·8	52
54	1·0	1·1	1·2	1·3	1·4	1·5	1·7	1·8	1·9	2·0	2·1	2·2	2·3	2·4	2·5	2·6	2·7	2·8	2·9	3·0	3·1	3·2	3·3	3·4	3·5	3·6	3·7	3·8	3·9	4·0	4·1	54
56	1·1	1·2	1·3	1·4	1·5	1·7	1·8	1·9	2·0	2·1	2·2	2·3	2·4	2·5	2·6	2·8	2·9	3·0	3·1	3·2	3·3	3·4	3·5	3·6	3·7	3·9	4·0	4·1	4·2	4·2	4·4	56
58	1·2	1·3	1·4	1·5	1·6	1·8	1·9	2·0	2·1	2·2	2·4	2·5	2·6	2·7	2·8	2·9	3·1	3·2	3·3	3·4	3·5	3·6	3·8	3·9	4·0	4·1	4·2	4·3	4·5	4·6	4·7	58
60	1·3	1·4	1·5	1·6	1·7	1·9	2·0	2·1	2·2	2·4	2·5	2·6	2·7	2·9	3·0	3·1	3·2	3·4	3·5	3·6	3·7	3·9	4·0	4·1	4·2	4·4	4·5	4·6	4·7	4·9	5·0	60
62	1·3	1·5	1·6	1·7	1·9	2·0	2·1	2·3	2·4	2·5	2·7	2·8	2·9	3·1	3·2	3·3	3·5	3·6	3·7	3·9	4·0	4·1	4·2	4·4	4·5	4·7	4·8	4·9	5·0	5·2	5·3	62
64	1·4	1·6	1·7	1·8	2·0	2·1	2·3	2·4	2·5	2·7	2·8	3·0	3·1	3·2	3·4	3·5	3·7	3·8	3·9	4·1	4·2	4·4	4·5	4·6	4·8	4·9	5·1	5·2	5·4	5·5	5·6	64
66	1·5	1·6	1·8	1·9	2·1	2·2	2·4	2·5	2·7	2·8	3·0	3·1	3·3	3·4	3·6	3·7	3·9	4·0	4·1	4·3	4·4	4·6	4·7	4·9	5·0	5·2	5·3	5·5	5·6	5·8	5·9	66
68	1·6	1·7	1·9	2·0	2·2	2·3	2·5	2·7	2·8	3·0	3·1	3·3	3·4	3·6	3·7	3·9	4·1	4·2	4·4	4·5	4·7	4·8	5·0	5·2	5·3	5·5	5·6	5·8	5·9	6·1	6·3	68
70	1·6	1·8	2·0	2·1	2·3	2·5	2·6	2·8	3·0	3·1	3·3	3·5	3·6	3·8	3·9	4·1	4·3	4·4	4·6	4·8	4·9	5·1	5·3	5·4	5·6	5·8	5·9	6·1	6·2	6·4	6·6	70
72	1·7	1·9	2·1	2·3	2·4	2·6	2·8	2·9	3·1	3·3	3·5	3·6	3·8	4·0	4·2	4·3	4·5	4·7	4·8	5·0	5·2	5·4	5·5	5·7	5·9	6·1	6·2	6·4	6·6	6·7	6·9	72
74	1·8	2·0	2·2	2·4	2·5	2·7	2·9	3·1	3·3	3·4	3·6	3·8	4·0	4·2	4·3	4·5	4·7	4·9	5·1	5·3	5·4	5·6	5·8	6·0	6·2	6·3	6·5	6·7	6·9	7·1	7·2	74
76	1·9	2·1	2·3	2·5	2·7	2·8	3·0	3·2	3·4	3·6	3·8	4·0	4·2	4·4	4·5	4·7	4·9	5·1	5·3	5·5	5·7	5·9	6·1	6·2	6·4	6·6	6·8	7·0	7·2	7·4	7·6	76
78	2·0	2·2	2·4	2·6	2·8	3·0	3·2	3·4	3·6	3·8	4·0	4·2	4·4	4·6	4·7	4·9	5·1	5·3	5·5	5·7	5·9	6·1	6·3	6·5	6·7	6·9	7·1	7·3	7·5	7·7	7·9	78
80	2·1	2·3	2·5	2·7	2·9	3·1	3·3	3·5	3·7	3·9	4·1	4·3	4·5	4·7	5·0	5·2	5·4	5·6	5·8	6·0	6·2	6·4	6·6	6·8	7·0	7·2	7·4	7·6	7·8	8·0	8·3	80
82	2·2	2·4	2·6	2·8	3·0	3·2	3·4	3·7	3·9	4·1	4·3	4·5	4·7	5·0	5·2	5·4	5·6	5·8	6·0	6·2	6·5	6·7	6·9	7·1	7·3	7·5	7·7	8·0	8·2	8·4	8·6	82
84	2·2	2·5	2·7	2·9	3·1	3·4	3·6	3·8	4·0	4·3	4·5	4·7	4·9	5·2	5·4	5·6	5·8	6·0	6·3	6·5	6·7	6·9	7·2	7·4	7·6	7·8	8·1	8·3	8·5	8·7	9·0	84
86	2·3	2·6	2·8	3·0	3·3	3·5	3·7	4·0	4·2	4·4	4·7	4·9	5·1	5·4	5·6	5·8	6·0	6·3	6·5	6·7	7·0	7·2	7·5	7·7	7·9	8·1	8·4	8·6	8·8	9·1	9·3	86
88	2·4	2·7	2·9	3·1	3·4	3·6	3·9	4·1	4·3	4·6	4·8	5·1	5·3	5·6	5·8	6·0	6·3	6·5	6·8	7·0	7·2	7·5	7·7	8·0	8·2	8·5	8·7	8·9	9·2	9·4	9·7	88
90	2·5	2·8	3·0	3·3	3·5	3·8	4·0	4·3	4·5	4·8	5·0	5·3	5·5	5·8	6·0	6·3	6·5	6·8	7·0	7·3	7·5	7·8	8·0	8·3	8·5	8·8	9·0	9·3	9·5	9·8	10·0	90

ADMIRALTY TIDE TABLES—Part II.

No.	Reference	Place	Position Lat.	Position Long.	Harmonic Constants M₂ g	M₂ H	S₂ g	S₂ H	K₁ g	K₁ H	O₁ g	O₁ H	M_0	Time Difference	Ratio
			° ′	° ′	g	H	g	H	g	H	g	H	ft.	H.M.	
					Time Meridian: Greenwich (ST.: 0000)										
			N.	W.										*On Devonport*	
2	R*	Penzance	50 06	5 33	135	5·6	170	1·9	108	0·2	339	0·2	9·7	−0038	1·02
3	R*i	Lizard Head	49 57	5 12	136	5·2	181	1·9	108	0·2	339	0·2	10·1	−0035	0·92
8	R*i	Fowey	50 20	4 38	148	5·4	201	2·1	111	0·3	336	0·2	8·9	−0011	0·98
14	—	**DEVONPORT** .	50 22	4 11	153	5·5	211	2·1	113	0·2	334	0·2	8·2	—	—
15	R*ir	Cargreen . .	50 26	4 12	161	4·4	210	1·7	115	0·3	334	0·2	8·2	+0015	0·80
26	*ir	Teignmouth . .	50 33	3 30	168	4·5	210	1·4	105	0·3	341	0·2	6·5	+0041 +0002	0·82
47	*	Southampton .	50 54	1 23	329	4·5	015	1·3	114	0·3	005	0·1	7·0	—	—
				E.										*On Dover*	
87	*i	Dungeness . .	50 54	0 58	327	8·8	016	2·8	070	0·1	198	0·1	11·9	−0015	1·20
88	*	Folkestone . .	51 05	1 11	330	8·0	019	2·8	058	0·1	168	0·1	10·3	−0009	1·09
89	*	**DOVER** . .	51 07	1 19	330	7·3	021	2·3	039	0·1	175	0·2	9·3	—	—
102	*	Ramsgate . .	51 20	1 25	341	6·1	033	1·9	017	0·2	179	0·3	8·0	+0014	0·84
				W.											
116	*	**LONDON BRIDGE**	51 30	0 05	036	8·0	102	2·2	030	0·4	213	0·4	11·0	—	—
173	—	**IMMINGHAM** .	53 37	0 11	161	7·3	210	2·4	279	0·5	120	0·5	11·3	—	—
														On River Tees	
186	ir	Middlesbrough .	54 35	1 13	113	5·2	152	1·7	261	0·4	104	0·4	9·1	−0012	1·00
188	—	Hartlepool . .	54 41	1 11	098	5·2	139	1·7	247	0·4	085	0·4	8·7	−0020	1·01
														On P. of Bristol	
528	*i	Walton Bay .	51 27	2 50	198	13·6	255	4·8	143	0·2	005	0·2	21·4	−0009	0·98
														On Kingstown	
610	*	Dublin (North Wall)	53 21	6 13	326	4·4	008	1·2	170	0·3	010	0·4	6·5	−0016	1·01
					Time Meridian 30° E. (ST.: −0200)									*On Kem*	
			N.	E.											
1066	*i	Onega . .	63 56	38 01	256	3·8	314	0·6	128	0·2	—	—	7·2	+0342 +0417	2·00
					Time Meridian: 15 E. (ST.: −0100)										
1436	*	Wilhelmshaven	53 31	8 09	011	5·0	086	1·3	049	0·2	255	0·3	6·6	—	—
					Time Meridian: 15° E. (ST.: −0100)									*On Helgoland*	
1446	*i	Norddeich hafen	53 37	7 10	328	3·6	039	0·9	044	0·2	245	0·3	4·4	−0017 −0013	1·04
				W.	*Time Meridian:* 11° W. (ST.: −0044)								Z°	*On Sierra Leone*	
2065	ir	Cape Palmas .	4 22	7 44	119	1·2	148	0·4	337	0·3	280	0·1	3·0	−0245	0·37
			S.		*Time Meridian:* 60° W. (ST.: +0400)										
2384	—	Puerto Belgrano . (Bahia Blanca)	38 53	62 06	147	1·7	282	0·8	044	0·7	347	0·5	8·0	—	—
			N.		*Time Meridian:* 75° W. (ST.: +0500)										
2905	—	Sandy Hook .	40 28	74 01	221	2·1	243	0·5	100	0·3	103	0·2	2·3	—	—
					Time Meridian: 60° W. (ST.: +0400)										
3015	—	St. John . .	45 15	66 04	342	9·8	016	1·6	134	0·5	110	0·4	13·7	—	—
					Time Meridian: 60° W. (ST.: +0400)									*On St. John*	
3032	i	Burntcoat Head .	45 18	63 49	018	20·0	049	3·2	160	0·8	143	0·6	26·9	+0113	2·04
				E.	*Time Meridian:* 105° E. (ST.: −0700)										
5432	—	Pakhoi . . .	21 29	109 04	164	1·3	201	0·4	072	3·1	038	3·4	9·7	—	—
			S.		*Time Meridian:* 150° E. (ST.: −1000)										
6326	†	Thursday Island .	10 35	142 13	066	1·2	330	1·1	205	1·9	146	1·0	6·6	—	—
					Time Meridian: 142° 30′ E. (ST.: −0930)									*On Darwin*	
6362	†	Darwin . . .	12 28	130 51	158	6·6	217	3·4	348	1·9	315	1·1	12·6	—	—
					Time Meridian: LOCAL									*On Auckland*	
6911	‡r	Macquarie Is. .	54 37	158 54	002	·90	042	·27	033	·28	354	·27	1·8	−0630	0·24
			S.		*Time Meridian:* (185° E.) (ST.: −1220)									*On Apia*	
6932	—	Nomuka . .	20 16	185 12	183	1·7	200	0·2	255	0·2	201	0·1	3·1	−0101	1·33
			N.	W.	*Time Meridian:* (120° W.) (ST.: +0800)										
8041	†	Victoria . .	48 26	123 23	085	1·2	094	0·3	149	2·1	136	1·2	6·1	—	—

ADMIRALTY TIDE TABLES II.

TABLE 4.—1939 Astronomical Data.

Day	January Transit	January H.P.	February Transit	February H.P.	March Transit	March H.P.	April Transit	April H.P.	May Transit	May H.P.	June Transit	June H.P.	July Transit	July H.P.	August Transit	August H.P.	September Transit	September H.P.	October Transit	October H.P.	November Transit	November H.P.	December Transit	December H.P.	Day
	H.M.	′	H.M.	′	H.M.	′	H.M.	′	H.M.	′	H.M	′	H.M.	′	H.M.	′	H.M.	′	H.M.	′	H.M.	′	H.M	′	
1	0742	58·1	0917	60·5	0802	59·9	0938	60·2	1006	58·8	1126	56·5	1154	54·9	0033	54·0	0123	54·5	0135	55·7	0257	57·8	0337	59·1	1
2	0837	59·1	1018	61·1	0901	60·5	1031	60·1	1058	58·4	1218	56·0	0018	54·6	0117	54·0	0206	54·8	0223	56·2	0352	58·2	0432	59·2	2
3	0935	60·0	1119	61·4	0959	60·9	1124	59·8	1150	57·9	0044	55·5	0106	54·3	0159	54·1	0250	55·3	0314	56·7	0447	58·6	0524	59·2	3
4	1036	60·8	1218	61·4	1056	61·0	1217	59·2	0017	57·2	0135	55·0	0152	54·1	0241	54·3	0337	55·8	0406	57·3	0541	59·0	0616	59·2	4
5	1139	61·2	0047	61·1	1152	60·8	0043	58·5	0110	56·6	0224	54·6	0236	54·1	0323	54·7	0425	56·5	0500	58·0	0635	59·4	0707	59·1	5
6	0010	61·4	0142	60·5	0019	60·4	0136	57·8	0202	55·9	0311	54·4	0318	54·1	0407	55·2	0517	57·3	0556	58·6	0727	59·6	0759	58·9	6
7	0111	61·2	0236	59·6	0113	59·7	0229	56·9	0254	55·3	0356	54·2	0401	54·3	0452	55·8	0611	58·1	0651	59·3	0820	59·7	0851	58·6	7
8	0209	60·7	0328	58·7	0206	58·8	0322	56·2	0343	54·8	0439	54·2	0443	54·7	0540	56·5	0707	59·0	0747	59·9	0913	59·7	0944	58·2	8
9	0304	60·0	0419	57·7	0258	57·9	0413	55·5	0431	54·5	0522	54·4	0526	55·2	0631	57·4	0804	59·8	0842	60·3	1006	59·5	1038	57·7	9
10	0357	59·2	0509	56·8	0350	57·0	0503	54·9	0517	54·3	0604	54·7	0611	55·9	0725	58·4	0902	60·5	0936	60·6	1100	59·1	1132	57·2	10
11	0447	58·3	0600	55·9	0442	56·1	0552	54·6	0601	54·3	0647	55·2	0658	56·7	0822	59·3	1000	61·0	1031	60·6	1155	58·6	1226	56·6	11
12	0537	57·4	0650	55·2	0533	55·4	0638	54·3	0644	54·4	0732	55·9	0748	57·6	0921	60·2	1056	61·2	1125	60·4	0022	57·9	0052	56·1	12
13	0626	56·6	0739	54·7	0623	54·8	0723	54·2	0727	54·7	0818	56·7	0842	58·5	1021	60·9	1152	61·2	1220	59·9	0117	57·2	0143	55·3	13
14	0715	55·9	0828	54·3	0711	54·4	0807	54·3	0810	55·2	0908	57·5	0940	59·4	1120	61·3	0020	60·8	0048	59·1	0211	56·5	0232	55·0	14
15	0804	55·3	0915	54·1	0758	54·1	0850	54·5	0854	55·7	1002	58·3	1039	60·2	1218	61·4	0115	60·1	0143	58·3	0304	55·8	0319	54·6	15
16	0853	54·8	1002	54·0	0843	54·1	0933	54·9	0940	56·4	1058	59·1	1140	60·7	0046	61·2	0209	59·2	0238	57·6	0353	55·2	0403	54·3	16
17	0942	54·4	1047	54·0	0928	54·1	1016	55·4	1029	57·1	1157	59·7	0010	61·0	0142	60·6	0303	58·3	0332	56·6	0440	54·7	0446	54·2	17
18	1031	54·2	1131	54·0	1011	54·3	1101	55·9	1121	57·8	0027	60·1	0109	61·0	0236	59·9	0357	57·4	0424	55·8	0526	54·4	0528	54·3	18
19	1118	54·0	1214	54·2	1054	54·6	1149	56·5	1216	58·4	0127	60·3	0206	60·7	0329	59·0	0450	56·5	0514	55·1	0609	54·2	0611	54·5	19
20	1204	53·9	0035	54·5	1137	54·9	0013	57·0	0044	58·9	0226	60·3	0301	60·2	0422	58·1	0542	55·7	0601	54·6	0652	54·3	0654	54·9	20
21	0027	53·9	0118	54·8	1221	55·3	0104	57·5	0142	59·3	0322	60·1	0354	59·5	0514	57·2	0632	55·1	0647	54·3	0734	54·5	0738	55·5	21
22	0111	54·0	0201	55·2	0044	55·8	0158	58·0	0241	59·5	0416	59·7	0445	58·7	0606	56·4	0720	54·6	0731	54·2	0817	54·8	0825	56·2	22
23	0154	54·2	0246	55·7	0130	56·2	0253	58·4	0338	59·6	0508	59·1	0537	57·9	0657	55·7	0807	54·3	0814	54·2	0901	55·3	0915	56·9	23
24	0230	54·5	0332	56·2	0219	56·8	0350	58·7	0434	59·5	0559	58·6	0628	57·1	0747	55·1	0851	54·1	0850	54·3	0947	55·9	1008	57·7	24
25	0319	54·9	0421	56·9	0309	57·3	0447	59·0	0528	59·3	0649	58·0	0719	56·4	0836	54·6	0935	54·0	0939	54·6	1036	56·5	1103	58·5	25
26	0402	55·4	0512	57·6	0403	57·8	0543	59·2	0620	59·1	0730	57·4	0810	55·8	0924	54·3	1017	54·1	1023	54·9	1127	57·1	1201	59·1	26
27	0447	56·1	0607	58·4	0458	58·3	0638	59·3	0711	58·8	0830	56·8	0900	55·3	1009	54·1	1100	54·3	1108	55·4	1221	57·7	0030	59·6	27
28	0534	56·9	0704	59·1	0555	58·9	0731	59·4	0801	58·4	0921	56·3	0950	54·9	1054	54·0	1143	54·5	1155	55·8	0049	58·2	0128	59·9	28
29	0625	57·8			0652	59·4	0823	59·3	0851	58·0	1013	55·8	1039	54·5	1137	54·0	0004	54·8	0019	56·3	0145	58·6	0225	60·0	29
30	0719	58·7			0748	59·8	0914	59·1	0942	57·5	1104	55·4	1126	54·3	1219	54·0	0049	55·2	0110	56·8	0242	58·9	0320	59·9	30
31	0817	59·7			0843	60·1			1034	57·0			1211	54·1	0040	54·2			0202	57·3			0413	59·6	31

TABLE I. A.T.T. II. SHALLOW WATER CORRECTIONS.

No.	Place	Correction to H.W. Time	H.W. Height	L.W. Time	L.W. Height
		H. M.	FT.	H. M.	FT.
2	Penzance - - -	−00 02	+0·2	+00 13	−0·2
47	Southampton - -	−00 35 +01 20	0·5 +0·4	−00 13	−0·5
89	Dover - - - -	−00 22	0·0	+00 41	0·0
116	London Bridge - -	+00 03	+1·1	+00 27	+1·1
616	Dublin North Wall -	+00 06	+0·2	−00 10	+0·2

TABLE II. A.T.T. II. SEASONAL CORRECTIONS.

No.	Place	Feb.	March	April	May	June
		F.	F.	F.	F.	F.
6326	Thursday Island -	+0·4	+0·5	+0·4	+0·1	−0·3
6362	Darwin - - -	−1·1	−0·2	+0·8	+1·3	+1·1

EXTRACTS FROM ADMIRALTY TIDE TABLES—Part III.

TABLE 1.—*b*, B.

Corrections for Year and Date.

1939								
Date	M_2		S_2		K_1		O_1	
	b	B	*b*	B	*b*	B	*b*	B
	°		°		°		°	
Jan. 1	−1	1·03	8	0·89	351	1·21	19	0·85
11	−1	1·03	11	0·94	346	1·16	29	0·85
21	−1	1·03	13	1·02	340	1·08	38	0·85
31	−1	1·03	13	1·09	334	0·99	48	0·85
Feb. 10	−1	1·03	12	1·15	326	0·88	58	0·85
20	−1	1·03	10	1·20	315	0·76	68	0·85
Mar. 2	−1	1·03	7	1·23	301	0·66	78	0·85
12	−1	1·03	4	1·24	282	0·59	88	0·85
22	−1	1·03	1	1·22	260	0·58	98	0·85
Apr. 1	−1	1·03	− 2	1·19	241	0·63	107	0·85
11	−1	1·03	− 5	1·14	223	0·73	117	0·85
21	−1	1·03	− 8	1·07	210	0·85	127	0·85
May 1	−1	1·03	−10	0·99	201	0·97	137	0·85
11	−1	1·03	−10	0·91	195	1·06	147	0·85
21	−1	1·03	− 9	0·83	190	1·14	157	0·85
31	−1	1·03	− 6	0·77	185	1·19	167	0·85
June 10	−1	1·03	− 2	0·74	181	1·23	176	0·85
20	−1	1·03	3	0·73	176	1·24	186	0·85
30	−1	1·03	8	0·77	172	1·22	196	0·85

1939								
Date	M_2		S_2		K_1		O_1	
	b	B	*b*	B	*b*	B	*b*	B
	°		°		°		°	
July 10	−1	1·03	11	0·81	167	1·18	206	0·85
20	−1	1·03	12	0·88	162	1·10	216	0·85
30	−1	1·03	12	0·95	156	1·01	226	0·85
Aug. 9	−1	1·03	10	1·03	148	0·91	235	0·85
19	−1	1·03	7	1·09	138	0·79	245	0·85
29	−1	1·03	4	1·15	125	0·69	255	0·85
Sept. 8	−1	1·03	0	1·18	107	0·61	265	0·85
18	−1	1·03	− 4	1·20	87	0·58	275	0·85
28	−1	1·03	− 7	1·20	66	0·61	285	0·85
Oct. 8	−1	1·03	−10	1·18	47	0·70	295	0·85
18	−1	1·03	−13	1·14	33	0·82	304	0·85
28	−1	1·03	−14	1·08	23	0·94	314	0·85
Nov. 7	−1	1·03	−15	1·02	16	1·04	324	0·85
17	−1	1·03	−14	0·95	11	1·12	334	0·85
27	−1	1·03	−11	0·89	6	1·18	344	0·85
Dec. 7	−1	1·03	− 6	0·85	2	1·22	354	0·85
17	−1	1·03	0	0·84	358	1·24	4	0·85
27	−1	1·03	5	0·86	353	1·23	14	0·85
Jan. 6	−1	1·03	9	0·91	348	1·19	23	0·85

EXTRACTS FROM ADMIRALTY TIDE TABLES—Part III.

TABLE 2.—*c*, C.

(*a*) Values of *c* (for M_2 and O_1 only). Angles according to Adjusted Times of Moon's Transit.

Time of Moon's Transit.

Hrs. / Mins.	0	1	2	3	4	5	6	7	8	9	10	11	12
	°	°	°	°	°	°	°	°	°	°	°	°	°
0	0	29	58	87	116	145	174	203	232	261	290	319	348
2	1	30	59	88	117	146	175	204	233	262	291	320	349
4	2	31	60	89	118	147	176	205	234	263	292	321	350
6	3	32	61	90	119	148	177	206	235	264	293	322	351
8	4	33	62	91	120	149	178	207	236	265	294	323	352
10	5	34	63	92	121	150	179	208	237	266	295	324	353
12	6	35	64	93	122	151	180	209	238	267	296	325	354
14	7	36	65	94	123	152	181	210	239	268	297	326	355
16	8	37	66	95	124	153	182	211	240	269	298	327	356
18	9	38	67	96	125	154	183	212	241	270	299	328	357
20	10	39	68	97	126	155	184	213	242	271	300	328	357
22	11	40	69	98	127	156	185	214	243	271	300	329	358
24	12	41	70	99	128	157	185	214	243	272	301	330	359
26	13	42	71	100	128	157	186	215	244	273	302	331	0
28	14	43	71	100	129	158	187	216	245	274	303	332	1
30	14	43	72	101	130	159	188	217	246	275	304	333	2
32	15	44	73	102	131	160	189	218	247	276	305	334	3
34	16	45	74	103	132	161	190	219	248	277	306	335	4
36	17	46	75	104	133	162	191	220	249	278	307	336	5
38	18	47	76	105	134	163	192	221	250	279	308	337	6
40	19	48	77	106	135	164	193	222	251	280	309	338	7
42	20	49	78	107	136	165	194	223	252	281	310	339	8
44	21	50	79	108	137	166	195	224	253	282	311	340	9
46	22	51	80	109	138	167	196	225	254	283	312	341	10
48	23	52	81	110	139	168	197	226	255	284	313	342	11
50	24	53	82	111	140	169	198	227	256	285	314	343	12
52	25	54	83	112	141	170	199	228	257	286	315	344	13
54	26	55	84	113	142	171	200	229	258	287	316	345	14
56	27	56	85	114	143	172	201	230	259	288	317	346	15
58	28	57	86	115	144	173	202	231	260	289	318	347	16
60	29	58	87	116	145	174	203	232	261	290	319	348	17

If adjusted time of Moon's transit is greater than 13h., subtract 12h. 25m.

(*b*) Values of C. Corrections for Moon's Parallax.

H.P.	M_2	S_2	K_1	O_1
52′	0·76	—	0·84	0·76
53	0·80	—	0·86	0·80
54	0·85	—	0·90	0·85
55	0·90	—	0·93	0·90
56	0·95	—	0·97	0·95
57	1·00	—	1·00	1·00
58	1·05	—	1·03	1·05
59	1·11	—	1·07	1·11
60	1·16	—	1·11	1·16
61	1·22	—	1·15	1·22
62	1·28	—	1·19	1·28

TABLE 3.—*e*, E.

For Combining Constituents of the Same Species (Semidiurnal or Diurnal).

D \ *d*	0°		10°		20°		30°		40°		50°		60°		70°	
	e	E	*e*	E	*e*	E	*e*	E	*e*	E	*e*	E	*e*	E	*e*	E
	°		°		°		°		°		°		°		°	
0·0	0	1·0	0	1·0	0	1·0	0	1·0	0	1·0	0	1·0	0	1·0	0	1·0
0·1	0	1·1	1	1·1	2	1·1	3	1·1	3	1·1	4	1·1	5	1·1	5	1·0
0·2	0	1·2	2	1·2	3	1·2	5	1·2	6	1·2	8	1·1	9	1·1	10	1·1
0·3	0	1·3	2	1·3	5	1·3	7	1·3	9	1·3	11	1·2	13	1·2	14	1·1
0·4	0	1·4	3	1·4	6	1·4	9	1·4	11	1·3	14	1·3	16	1·3	18	1·2
0·5	0	1·5	3	1·5	7	1·5	10	1·5	13	1·4	16	1·4	19	1·3	22	1·3
0·6	0	1·6	4	1·6	8	1·6	11	1·6	15	1·5	18	1·5	22	1·4	25	1·3
0·7	0	1·7	4	1·7	8	1·7	12	1·6	16	1·6	20	1·6	24	1·5	28	1·4
0·8	0	1·8	5	1·8	9	1·8	13	1·7	18	1·7	22	1·6	26	1·6	31	1·5
0·9	0	1·9	5	1·9	10	1·9	14	1·8	19	1·8	24	1·7	28	1·7	33	1·6
1·0	0	2·0	5	2·0	10	2·0	15	1·9	20	1·9	25	1·8	30	1·7	35	1·6
1·1	0	2·1	5	2·1	11	2·1	16	2·0	21	2·0	26	1·9	32	1·8	37	1·7
1·2	0	2·2	6	2·2	11	2·2	16	2·1	22	2·1	27	2·0	33	1·9	39	1·8
1·3	0	2·3	6	2·3	11	2·3	17	2·2	23	2·2	28	2·1	34	2·0	40	1·9
1·4	0	2·4	6	2·4	12	2·4	18	2·3	24	2·3	29	2·2	35	2·1	42	2·0
1·5	0	2·5	6	2·5	12	2·5	18	2·4	24	2·4	30	2·3	36	2·2	43	2·1
1·6	0	2·6	6	2·6	12	2·6	19	2·5	25	2·5	31	2·4	37	2·3	44	2·2
1·7	0	2·7	6	2·7	13	2·7	19	2·6	25	2·6	32	2·5	38	2·4	45	2·3
1·8	0	2·8	6	2·8	13	2·8	19	2·7	26	2·7	33	2·6	39	2·5	46	2·3
1·9	0	2·9	7	2·9	13	2·9	20	2·8	27	2·7	33	2·7	40	2·6	47	2·4
2·0	0	3·0	7	3·0	14	3·0	20	2·9	27	2·8	34	2·8	41	2·7	48	2·5
2·1	0	3·1	7	3·1	14	3·1	20	3·0	27	2·9	34	2·8	42	2·8	49	2·6
2·2	0	3·2	7	3·2	14	3·2	21	3·1	28	3·0	35	2·9	42	2·8	50	2·7
2·3	0	3·3	7	3·3	14	3·3	21	3·2	28	3·1	35	3·0	43	2·9	50	2·8
2·4	0	3·4	7	3·4	14	3·4	21	3·3	29	3·2	36	3·1	43	3·0	51	2·9
2·5	0	3·5	7	3·5	14	3·5	22	3·4	29	3·3	36	3·2	44	3·1	52	3·0
2·6	0	3·6	7	3·6	15	3·6	22	3·5	29	3·4	37	3·3	44	3·2	52	3·1
2·7	0	3·7	7	3·7	15	3·7	22	3·6	30	3·5	37	3·4	45	3·3	53	3·2
2·8	0	3·8	7	3·8	15	3·8	22	3·7	30	3·6	38	3·5	45	3·4	53	3·3
2·9	0	3·9	8	3·9	15	3·9	23	3·8	30	3·7	38	3·6	46	3·5	54	3·4
3·0	0	4·0	8	4·0	15	4·0	23	3·9	30	3·8	38	3·7	46	3·6	54	3·5
3·1	0	4·1	8	4·1	15	4·1	23	4·0	31	3·9	38	3·8	46	3·7	55	3·6
3·2	0	4·2	8	4·2	15	4·2	23	4·1	31	4·0	39	3·9	47	3·8	55	3·7
3·3	0	4·3	8	4·3	15	4·3	23	4·2	31	4·1	39	4·0	47	3·9	56	3·8
3·4	0	4·4	8	4·4	16	4·4	23	4·3	31	4·2	39	4·1	48	4·0	56	3·9
3·5	0	4·5	8	4·5	16	4·5	23	4·4	31	4·3	40	4·2	48	4·1	56	4·0
3·6	0	4·6	8	4·6	16	4·6	24	4·5	32	4·4	40	4·3	48	4·2	57	4·1
3·7	0	4·7	8	4·7	16	4·7	24	4·6	32	4·5	40	4·4	48	4·3	57	4·2
3·8	0	4·8	8	4·8	16	4·8	24	4·7	32	4·6	40	4·5	49	4·4	57	4·3
3·9	0	4·9	8	4·9	16	4·9	24	4·8	32	4·7	40	4·6	49	4·5	58	4·4
4·0	0	5·0	8	5·0	16	5·0	24	4·9	32	4·8	41	4·7	49	4·6	58	4·4
4·2	0	5·2	8	5·2	16	5·2	24	5·1	33	5·0	41	4·9	50	4·8	58	4·6
4·4	0	5·4	8	5·4	16	5·4	25	5·3	33	5·2	41	5·1	50	5·0	59	4·8
4·6	0	5·6	8	5·6	17	5·6	25	5·5	33	5·4	42	5·3	50	5·2	59	5·0
4·8	0	5·8	8	5·8	17	5·8	25	5·7	33	5·6	42	5·5	51	5·4	60	5·2
5·0	0	6·0	8	6·0	17	6·0	25	5·9	34	5·8	42	5·7	51	5·6	60	5·4
5·2	0	6·2	8	6·2	17	6·2	25	6·1	34	6·0	43	5·9	51	5·8	60	5·6
5·4	0	6·4	8	0·4	17	6·4	25	6·3	34	6·2	43	6·1	52	6·0	61	5·8
5·6	0	6·6	8	6·6	17	6·6	26	6·5	34	6·4	43	6·3	52	6·2	61	6·0
5·8	0	6·8	9	6·8	17	6·8	26	6·7	34	6·6	43	6·5	52	6·4	61	6·2
6·0	0	7·0	9	7·0	17	7·0	26	6·9	35	0·8	44	6·7	52	6·6	62	6·4
6·5	0	7·5	9	7·5	17	7·5	26	7·4	35	7·3	44	7·2	53	7·1	62	6·9
7·0	0	8·0	9	8·0	18	8·0	26	7·9	35	7·8	44	7·7	54	7·6	63	7·4
7·5	0	8·5	9	8·5	18	8·5	27	8·4	36	8·3	44	8·2	54	8·1	63	7·9
8·0	0	9·0	9	9·0	18	9·0	27	8·9	36	8·8	45	8·7	54	8·6	64	8·4
8·5	0	9·5	9	9·5	18	9·5	27	9·4	36	9·3	45	9·2	55	9·1	64	8·9
9·0	0	10·0	9	10·0	18	10·0	27	9·9	36	9·8	46	9·7	55	9·5	64	9·4
9·5	0	10·5	9	10·5	18	10·5	27	10·4	36	10·3	46	10·2	55	10·0	65	9·9
10·0	0	11·0	9	11·0	18	11·0	27	10·9	37	10·8	46	10·7	55	10·5	65	10·4

If *d* is negative, *e* is negative.

TABLE 3.—*e*, E—*contd.*

For Combining Constituents of the Same Species (Semidiurnal or Diurnal).

D \ *d*	70°		80°		90°		100°		110°		120°		130°		140°	
	e	E	*e*	E	*e*	E	*e*	E	*e*	E	*e*	E	*e*	E	*e*	E
	°		°		°		°		°		°		°		°	
0·0	0	1·0	0	1·0	0	1·0	0	1·0	0	1·0	0	1·0	0	1·0	0	1·0
0·1	5	1·0	6	1·0	6	1·0	6	1·0	6	1·0	5	1·0	5	0·9	4	0·9
0·2	10	1·1	11	1·1	11	1·0	12	1·0	11	1·0	11	0·9	10	0·9	9	0·9
0·3	14	1·1	16	1·1	17	1·0	17	1·0	17	0·9	17	0·9	16	0·8	14	0·8
0·4	18	1·2	20	1·1	22	1·1	23	1·0	24	0·9	23	0·9	22	0·8	20	0·7
0·5	22	1·3	24	1·2	27	1·1	28	1·0	30	1·0	30	0·9	29	0·8	28	0·7
0·6	25	1·3	28	1·3	31	1·2	33	1·1	35	1·0	37	0·9	37	0·8	36	0·7
0·7	28	1·4	32	1·3	35	1·2	38	1·1	41	1·0	43	0·9	44	0·8	44	0·6
0·8	31	1·5	35	1·4	39	1·3	42	1·2	46	1·1	49	0·9	52	0·8	53	0·6
0·9	33	1·6	38	1·5	42	1·3	46	1·2	51	1·1	55	1·0	59	0·8	62	0·7
1·0	35	1·6	40	1·5	45	1·4	50	1·3	55	1·2	60	1·0	65	0·9	70	0·7
1·1	37	1·7	42	1·6	48	1·5	53	1·4	59	1·2	65	1·1	71	0·9	77	0·7
1·2	39	1·8	44	1·7	50	1·6	56	1·4	62	1·3	69	1·1	76	1·0	84	0·8
1·3	40	1·9	46	1·8	52	1·6	59	1·5	66	1·3	73	1·2	81	1·0	90	0·8
1·4	42	2·0	48	1·9	54	1·7	61	1·6	68	1·4	76	1·3	85	1·1	95	0·9
1·5	43	2·1	50	1·9	56	1·8	63	1·7	71	1·5	79	1·3	88	1·2	99	1·0
1·6	44	2·2	51	2·0	58	1·9	65	1·7	73	1·6	82	1·4	91	1·2	102	1·1
1·7	45	2·3	52	2·1	60	2·0	67	1·8	75	1·7	84	1·5	94	1·3	106	1·1
1·8	46	2·3	54	2·2	61	2·1	69	1·9	77	1·7	86	1·6	97	1·4	108	1·2
1·9	47	2·4	55	2·3	62	2·2	70	2·0	79	1·8	88	1·7	99	1·5	110	1·3
2·0	48	2·5	56	2·4	63	2·2	72	2·1	80	1·9	90	1·7	101	1·6	112	1·4
2·1	49	2·6	57	2·5	65	2·3	73	2·2	82	2·0	92	1·8	102	1·7	114	1·5
2·2	50	2·7	58	2·6	66	2·4	74	2·3	83	2·1	93	1·9	104	1·7	116	1·6
2·3	50	2·8	58	2·7	67	2·5	75	2·4	84	2·2	94	2·0	105	1·8	117	1·7
2·4	51	2·9	59	2·8	67	2·6	76	2·4	85	2·3	96	2·1	106	1·9	119	1·8
2·5	52	3·0	60	2·9	68	2·7	77	2·5	86	2·4	97	2·2	108	2·0	120	1·9
2·6	52	3·1	61	3·0	69	2·8	78	2·6	87	2·5	98	2·3	109	2·1	121	1·9
2·7	53	3·2	61	3·0	70	2·9	79	2·7	88	2·5	99	2·4	110	2·2	122	2·0
2·8	53	3·3	62	3·1	70	3·0	79	2·8	89	2·6	99	2·5	111	2·3	123	2·1
2·9	54	3·4	62	3·2	71	3·1	80	2·9	90	2·7	100	2·6	111	2·4	123	2·2
3·0	54	3·5	63	3·3	72	3·2	81	3·0	90	2·8	101	2·7	112	2·5	124	2·3
3·1	55	3·6	63	3·4	72	3·3	81	3·1	91	2·9	102	2·8	113	2·6	125	2·4
3·2	55	3·7	64	3·5	73	3·4	82	3·2	92	3·0	102	2·8	113	2·7	125	2·5
3·3	56	3·8	64	3·6	73	3·5	83	3·3	92	3·1	103	2·9	114	2·8	126	2·6
3·4	56	3·9	65	3·7	74	3·6	83	3·4	93	3·2	103	3·0	114	2·9	126	2·7
3·5	56	4·0	65	3·8	74	3·7	84	3·5	93	3·3	104	3·1	115	3·0	127	2·8
3·6	57	4·1	65	3·9	75	3·7	84	3·6	94	3·4	104	3·2	115	3·1	127	2·9
3·7	57	4·2	66	4·0	75	3·8	84	3·7	94	3·5	105	3·3	116	3·2	128	3·0
3·8	57	4·3	66	4·1	75	3·9	85	3·8	95	3·6	105	3·4	116	3·3	128	3·1
3·9	58	4·4	66	4·2	76	4·0	85	3·9	95	3·7	106	3·5	117	3·3	128	3·2
4·0	58	4·4	67	4·3	76	4·1	86	4·0	96	3·8	106	3·6	117	3·4	129	3·3
4·2	58	4·6	67	4·5	77	4·3	86	4·1	96	4·0	107	3·8	118	3·6	130	3·5
4·4	59	4·8	68	4·7	77	4·5	87	4·3	97	4·2	108	4·0	118	3·8	130	3·7
4·6	59	5·0	68	4·9	78	4·7	88	4·5	98	4·4	108	4·2	119	4·0	131	3·9
4·8	60	5·2	69	5·1	78	4·9	88	4·7	98	4·6	109	4·4	120	4·2	131	4·1
5·0	60	5·4	69	5·3	79	5·1	89	4·9	99	4·8	109	4·6	120	4·4	131	4·3
5·2	60	5·6	70	5·5	79	5·3	89	5·1	99	5·0	109	4·8	120	4·6	132	4·5
5·4	61	5·8	70	5·7	80	5·5	89	5·3	99	5·2	110	5·0	121	4·8	132	4·7
5·6	61	6·0	70	5·9	80	5·7	90	5·5	100	5·3	110	5·2	121	5·0	132	4·9
5·8	61	6·2	71	6·1	80	5·9	90	5·7	100	5·5	111	5·4	121	5·2	133	5·1
6·0	62	6·4	71	6·3	81	6·1	90	5·9	101	5·7	111	5·6	122	5·4	133	5·3
6·5	62	6·9	72	6·8	81	6·6	91	6·4	101	6·2	112	6·1	122	5·9	134	5·8
7·0	63	7·4	72	7·3	82	7·1	92	6·9	102	6·7	112	6·6	123	6·4	134	6·3
7·5	63	7·9	73	7·8	82	7·6	92	7·4	102	7·2	113	7·1	124	6·9	134	6·8
8·0	64	8·4	73	8·2	83	8·1	93	7·9	103	7·7	113	7·5	124	7·4	135	7·3
8·5	64	8·9	74	8·7	83	8·6	93	8·4	103	8·2	114	8·0	124	7·9	135	7·8
9·0	64	9·4	74	9·2	84	9·1	94	8·9	104	8·7	114	8·5	125	8·4	136	8·3
9·5	65	9·9	74	9·7	84	9·6	94	9·4	104	9·2	115	9·0	125	8·9	136	8·8
10·0	65	10·4	75	10·2	84	10·1	94	9·9	104	9·7	115	9·5	125	9·4	136	9·3

If *d* is negative, *e* is negative.

TABLE 3.—*e*, E—*contd.*

For Combining Constituents of the Same Species (Semidiurnal or Diurnal).

D \ d	140°		150°		160°		170°		180°		190°		200°		210°	
	e	E	*e*	E	*e*	E	*e*	E	*e*	E	*e*	E	*e*	E	*e*	E
	°		°		°		°		°		°		°		°	
0·0	0	1·0	0	1·0	0	1·0	0	1·0	0	1·0	0	1·0	0	1·0	0	1·0
0·1	4	0·9	3	0·9	2	0·9	1	0·9	0	0·9	359	0·9	358	0·9	357	0·9
0·2	9	0·9	7	0·8	5	0·8	2	0·8	0	0·8	358	0·8	355	0·8	353	0·8
0·3	14	0·8	11	0·8	8	0·7	4	0·7	0	0·7	356	0·7	352	0·7	349	0·8
0·4	20	0·7	17	0·7	12	0·6	7	0·6	0	0·6	353	0·6	348	0·6	343	0·7
0·5	28	0·7	24	0·6	18	0·6	10	0·5	0	0·5	350	0·5	342	0·6	336	0·6
0·6	36	0·7	32	0·6	25	0·5	14	0·4	0	0·4	346	0·4	335	0·5	328	0·6
0·7	44	0·6	42	0·5	35	0·4	21	0·4	0	0·3	339	0·3	325	0·4	318	0·5
0·8	53	0·6	53	0·5	48	0·4	33	0·3	0	0·2	327	0·3	312	0·4	307	0·5
0·9	62	0·7	64	0·5	63	0·3	54	0·2	0	0·1	306	0·2	297	0·3	296	0·5
1·0	70	0·7	75	0·5	80	0·3	85	0·2	—	0·0	275	0·2	280	0·3	285	0·5
1·1	77	0·7	85	0·6	95	0·4	113	0·2	180	0·1	247	0·2	265	0·4	275	0·6
1·2	84	0·8	94	0·6	107	0·4	131	0·3	180	0·2	229	0·3	253	0·4	266	0·6
1·3	90	0·8	101	0·7	117	0·5	141	0·4	180	0·3	219	0·4	243	0·5	259	0·7
1·4	95	0·9	107	0·7	123	0·6	147	0·5	180	0·4	213	0·5	237	0·6	253	0·7
1·5	99	1·0	112	0·8	129	0·7	151	0·5	180	0·5	209	0·5	231	0·7	248	0·8
1·6	102	1·1	116	0·9	133	0·7	154	0·6	180	0·6	206	0·6	227	0·7	244	0·9
1·7	106	1·1	119	1·0	136	0·8	156	0·7	180	0·7	204	0·7	224	0·8	241	1·0
1·8	108	1·2	122	1·1	138	0·9	158	0·8	180	0·8	202	0·8	222	0·9	238	1·1
1·9	110	1·3	124	1·2	140	1·0	159	0·9	180	0·9	201	0·9	220	1·0	236	1·2
2·0	112	1·4	126	1·2	142	1·1	160	1·0	180	1·0	200	1·0	218	1·1	234	1·2
2·1	114	1·5	128	1·3	143	1·2	161	1·1	180	1·1	199	1·1	217	1·2	232	1·3
2·2	116	1·6	130	1·4	145	1·3	162	1·2	180	1·2	198	1·2	215	1·3	230	1·4
2·3	117	1·7	131	1·5	146	1·4	162	1·3	180	1·3	198	1·3	214	1·4	229	1·5
2·4	119	1·8	132	1·6	147	1·5	163	1·4	180	1·4	197	1·4	213	1·5	228	1·6
2·5	120	1·9	133	1·7	148	1·6	163	1·5	180	1·5	197	1·5	212	1·6	227	1·7
2·6	121	1·9	134	1·8	148	1·7	164	1·6	180	1·6	196	1·6	212	1·7	226	1·8
2·7	122	2·0	135	1·9	119	1·8	164	1·7	180	1·7	196	1·7	211	1·8	225	1·9
2·8	123	2·1	136	2·0	150	1·9	165	1·8	180	1·8	195	1·8	210	1·9	224	2·0
2·9	123	2·2	136	2·1	150	2·0	165	1·9	180	1·9	195	1·9	210	2·0	224	2·1
3·0	124	2·3	137	2·2	151	2·1	165	2·0	180	2·0	195	2·0	209	2·1	223	2·2
3·1	125	2·4	137	2·3	151	2·2	165	2·1	180	2·1	195	2·1	209	2·2	223	2·3
3·2	125	2·5	138	2·4	151	2·3	166	2·2	180	2·2	194	2·2	209	2·3	222	2·4
3·3	126	2·6	138	2·5	152	2·4	166	2·3	180	2·3	194	2·3	208	2·4	222	2·5
3·4	126	2·7	139	2·6	152	2·5	166	2·4	180	2·4	194	2·4	208	2·5	221	2·6
3·5	127	2·8	139	2·7	152	2·6	166	2·5	180	2·5	194	2·5	208	2·6	221	2·7
3·6	127	2·9	140	2·8	153	2·7	166	2·6	180	2·6	194	2·6	207	2·7	220	2·8
3·7	128	3·0	140	2·9	153	2·8	166	2·7	180	2·7	194	2·7	207	2·8	220	2·9
3·8	128	3·1	140	3·0	153	2·9	166	2·8	180	2·8	194	2·8	207	2·9	220	3·0
3·9	128	3·2	141	3·1	153	3·0	166	2·9	180	2·9	194	2·9	207	3·0	219	3·1
4·0	129	3·3	141	3·2	154	3·1	167	3·0	180	3·0	193	3·0	206	3·1	219	3·2
4·2	130	3·5	142	3·4	154	3·3	167	3·2	180	3·2	193	3·2	206	3·3	218	3·4
4·4	130	3·7	142	3·6	155	3·5	167	3·4	180	3·4	193	3·4	205	3·5	218	3·6
4·6	131	3·9	142	3·8	155	3·7	167	3·6	180	3·6	193	3·6	205	3·7	218	3·8
4·8	131	4·1	143	4·0	155	3·9	167	3·8	180	3·8	193	3·8	205	3·9	217	4·0
5·0	131	4·3	143	4·2	155	4·1	168	4·0	180	4·0	192	4·0	205	4·1	217	4·2
5·2	132	4·5	143	4·4	155	4·3	168	4·2	180	4·2	192	4·2	205	4·3	217	4·4
5·4	132	4·7	144	4·6	156	4·5	168	4·4	180	4·4	192	4·4	204	4·5	216	4·6
5·6	132	4·9	144	4·8	156	4·7	168	4·6	180	4·6	192	4·6	204	4·7	216	4·8
5·8	133	5·1	144	5·0	156	4·9	168	4·8	180	4·8	192	4·8	204	4·9	216	5·0
6·0	133	5·3	144	5·2	156	5·1	168	5·0	180	5·0	192	5·0	204	5·1	216	5·2
6·5	134	5·8	145	5·7	156	5·6	168	5·5	180	5·5	192	5·5	204	5·6	215	5·7
7·0	134	6·3	145	6·2	157	6·1	168	6·0	180	6·0	192	6·0	203	6·1	215	6·2
7·5	134	6·8	146	6·7	157	6·6	168	6·5	180	6·5	192	6·5	203	6·6	214	6·7
8·0	135	7·3	146	7·2	157	7·1	169	7·0	180	7·0	191	7·0	203	7·1	214	7·2
8·5	135	7·8	146	7·7	157	7·6	169	7·5	180	7·5	191	7·5	203	7·6	214	7·7
9·0	136	8·3	147	8·2	158	8·1	169	8·0	180	8·0	191	8·0	202	8·1	213	8·2
9·5	136	8·8	147	8·7	158	8·6	169	8·5	180	8·5	191	8·5	202	8·6	213	8·7
10·0	136	9·3	147	9·2	158	9·1	169	9·0	180	9·0	191	9·0	202	9·1	213	9·2

If *d* is negative, *e* is negative.

TABLE 3.—*e*, E—*contd.*

For Combining Constituents of the Same Species (Semidiurnal or Diurnal).

D \ d	210°		220°		230°		240°		250°		260°		270°		280°	
	e	E	e	E	e	E	e	E	e	E	e	E	e	E	e	E
	°		°		°		°		°		°		°		°	
0·0	0	1·0	0	1·0	0	1·0	0	1·0	0	1·0	0	1·0	0	1·0	0	1·0
0·1	357	0·9	356	0·9	355	0·9	355	1·0	354	1·0	354	1·0	354	1·0	354	1·0
0·2	353	0·8	351	0·9	350	0·9	349	0·9	349	1·0	348	1·0	349	1·0	349	1·1
0·3	349	0·8	346	0·8	344	0·8	343	0·9	343	0·9	343	1·0	343	1·0	344	1·1
0·4	343	0·7	340	0·7	338	0·8	337	0·9	336	0·9	337	1·0	338	1·1	340	1·1
0·5	336	0·6	332	0·7	331	0·8	330	0·9	330	1·0	332	1·0	333	1·1	336	1·2
0·6	328	0·6	324	0·7	323	0·8	323	0·9	325	1·0	327	1·1	329	1·2	332	1·3
0·7	318	0·5	316	0·6	316	0·8	317	0·9	319	1·0	322	1·1	325	1·2	328	1·3
0·8	307	0·5	307	0·6	308	0·8	311	0·9	314	1·1	318	1·2	321	1·3	325	1·4
0·9	296	0·5	298	0·7	301	0·8	305	1·0	309	1·1	314	1·2	318	1·3	322	1·5
1·0	285	0·5	290	0·7	295	0·9	300	1·0	305	1·2	310	1·3	315	1·4	320	1·5
1·1	275	0·6	283	0·7	289	0·9	295	1·1	301	1·2	307	1·4	312	1·5	318	1·6
1·2	266	0·6	276	0·8	284	1·0	291	1·1	298	1·3	304	1·4	310	1·6	316	1·7
1·3	259	0·7	270	0·8	279	1·0	287	1·2	294	1·3	301	1·5	308	1·6	314	1·8
1·4	253	0·7	265	0·9	275	1·1	284	1·3	292	1·4	299	1·6	306	1·7	312	1·9
1·5	248	0·8	261	1·0	272	1·2	281	1·3	289	1·5	297	1·7	304	1·8	310	1·9
1·6	244	0·9	258	1·1	269	1·2	278	1·4	287	1·6	295	1·7	302	1·9	309	2·0
1·7	241	1·0	254	1·1	266	1·3	276	1·5	285	1·7	293	1·8	300	2·0	308	2·1
1·8	238	1·1	252	1·2	263	1·4	274	1·6	283	1·7	291	1·9	299	2·1	306	2·2
1·9	236	1·2	250	1·3	261	1·5	272	1·7	281	1·8	290	2·0	298	2·2	305	2·3
2·0	234	1·2	248	1·4	259	1·6	270	1·7	280	1·9	288	2·1	297	2·2	304	2·4
2·1	232	1·3	246	1·5	258	1·7	268	1·8	278	2·0	287	2·2	295	2·3	303	2·5
2·2	230	1·4	244	1·6	256	1·7	267	1·9	277	2·1	286	2·3	294	2·4	302	2·6
2·3	229	1·5	243	1·7	255	1·8	266	2·0	276	2·2	285	2·4	293	2·5	302	2·7
2·4	228	1·6	241	1·8	254	1·9	264	2·1	275	2·3	284	2·4	293	2·6	301	2·8
2·5	227	1·7	240	1·9	252	2·0	263	2·2	274	2·4	283	2·5	292	2·7	300	2·9
2·6	226	1·8	239	1·9	251	2·1	262	2·3	273	2·5	282	2·6	291	2·8	299	3·0
2·7	225	1·9	238	2·0	250	2·2	261	2·4	272	2·5	281	2·7	290	2·9	299	3·0
2·8	224	2·0	237	2·1	249	2·3	261	2·5	271	2·6	281	2·8	290	3·0	298	3·1
2·9	224	2·1	237	2·2	249	2·4	260	2·6	270	2·7	280	2·9	289	3·1	298	3·2
3·0	223	2·2	236	2·3	248	2·5	259	2·7	270	2·8	279	3·0	288	3·2	297	3·3
3·1	223	2·3	235	2·4	247	2·6	258	2·8	269	2·9	279	3·1	288	3·3	297	3·4
3·2	222	2·4	235	2·5	247	2·7	258	2·8	268	3·0	278	3·2	287	3·4	296	3·5
3·3	222	2·5	234	2·6	246	2·8	257	2·9	268	3·1	277	3·3	287	3·5	296	3·6
3·4	221	2·6	234	2·7	246	2·9	257	3·0	267	3·2	277	3·4	286	3·6	295	3·7
3·5	221	2·7	233	2·8	245	3·0	256	3·1	267	3·3	276	3·5	286	3·7	295	3·8
3·6	220	2·8	233	2·9	245	3·1	256	3·2	266	3·4	276	3·6	285	3·7	295	3·9
3·7	220	2·9	232	3·0	244	3·2	255	3·3	266	3·5	276	3·7	285	3·8	294	4·0
3·8	220	3·0	232	3·1	244	3·3	255	3·4	265	3·6	275	3·8	285	3·9	294	4·1
3·9	219	3·1	232	3·2	243	3·3	254	3·5	265	3·7	275	3·9	284	4·0	294	4·2
4·0	219	3·2	231	3·3	243	3·4	254	3·6	264	3·8	274	4·0	284	4·1	293	4·3
4·2	218	3·4	230	3·5	242	3·6	253	3·8	264	4·0	274	4·1	283	4·3	293	4·5
4·4	218	3·6	230	3·7	242	3·8	252	4·0	263	4·2	273	4·3	283	4·5	292	4·7
4·6	218	3·8	229	3·9	241	4·0	252	4·2	262	4·4	272	4·5	282	4·7	292	4·9
4·8	217	4·0	229	4·1	240	4·2	251	4·4	262	4·6	272	4·7	282	4·9	291	5·1
5·0	217	4·2	229	4·3	240	4·4	251	4·6	261	4·8	271	4·9	281	5·1	291	5·3
5·2	217	4·4	228	4·5	240	4·6	251	4·8	261	5·0	271	5·1	281	5·3	290	5·5
5·4	216	4·6	228	4·7	239	4·8	250	5·0	261	5·2	271	5·3	280	5·5	290	5·7
5·6	216	4·8	228	4·9	239	5·0	250	5·2	260	5·3	270	5·5	280	5·7	290	5·9
5·8	216	5·0	227	5·1	239	5·2	249	5·4	260	5·5	270	5·7	280	5·9	289	6·1
6·0	216	5·2	227	5·3	238	5·4	249	5·6	259	5·7	270	5·9	279	6·1	289	6·3
6·5	215	5·7	226	5·8	238	5·9	248	6·1	259	6·2	269	6·4	279	6·6	288	6·8
7·0	215	6·2	226	6·3	237	6·4	248	6·6	258	6·7	268	6·9	278	7·1	288	7·3
7·5	214	6·7	226	6·8	236	6·9	247	7·1	258	7·2	268	7·4	278	7·6	287	7·8
8·0	214	7·2	225	7·3	236	7·4	247	7·5	257	7·7	267	7·9	277	8·1	287	8·2
8·5	214	7·7	225	7·8	236	7·9	246	8·0	257	8·2	267	8·4	277	8·6	286	8·7
9·0	213	8·2	224	8·3	235	8·4	246	8·5	256	8·7	266	8·9	276	9·1	286	9·2
9·5	213	8·7	224	8·8	235	8·9	245	9·0	256	9·2	266	9·4	276	9·6	286	9·7
10·0	213	9·2	224	9·3	235	9·4	245	9·5	256	9·7	266	9·9	276	10·1	285	10·2

If *d* is negative, *e* is negative.

TABLE 3.—*e*, E—*contd.*
For Combining Constituents of the Same Species (Semidiurnal or Diurnal).

D \ d	280°		290°		300°		310°		320°		330°		340°		350°		360°	
	e	E	*e*	E	*e*	E	*e*	E	*e*	E	*e*	E	*e*	E	*e*	E	*e*	E
	°		°		°		°		°		°		°		°		°	
0·0	0	1·0	0	1·0	0	1·0	0	1·0	0	1·0	0	1·0	0	1·0	0	1·0	360	1·0
0·1	354	1·0	355	1·0	355	1·1	356	1·1	357	1·1	357	1·1	358	1·1	359	1·1	360	1·1
0·2	349	1·1	350	1·1	351	1·1	352	1·1	354	1·2	355	1·2	357	1·2	358	1·2	360	1·2
0·3	344	1·1	346	1·1	347	1·2	349	1·2	351	1·3	353	1·3	355	1·3	358	1·3	360	1·3
0·4	340	1·1	342	1·2	344	1·3	346	1·3	349	1·3	351	1·4	354	1·4	357	1·4	360	1·4
0·5	336	1·2	338	1·3	341	1·3	344	1·4	347	1·4	350	1·5	353	1·5	357	1·5	360	1·5
0·6	332	1·3	335	1·3	338	1·4	342	1·5	345	1·5	349	1·6	352	1·6	356	1·6	360	1·6
0·7	328	1·3	332	1·4	336	1·5	340	1·6	344	1·6	348	1·6	352	1·7	356	1·7	360	1·7
0·8	325	1·4	329	1·5	334	1·6	338	1·6	342	1·7	347	1·7	351	1·8	355	1·8	360	1·8
0·9	322	1·5	327	1·6	332	1·7	336	1·7	341	1·8	346	1·8	350	1·9	355	1·9	360	1·9
1·0	320	1·5	325	1·6	330	1·7	335	1·8	340	1·9	345	1·9	350	2·0	355	2·0	360	2·0
1·1	318	1·6	323	1·7	328	1·8	334	1·9	339	2·0	344	2·0	349	2·1	355	2·1	360	2·1
1·2	316	1·7	321	1·8	327	1·9	333	2·0	338	2·1	344	2·1	349	2·2	354	2·2	360	2·2
1·3	314	1·8	320	1·9	326	2·0	332	2·1	337	2·2	343	2·2	349	2·3	354	2·3	360	2·3
1·4	312	1·9	318	2·0	325	2·1	331	2·2	336	2·3	342	2·3	348	2·4	354	2·4	360	2·4
1·5	310	1·9	317	2·1	324	2·2	330	2·3	336	2·4	342	2·4	348	2·5	354	2·5	360	2·5
1·6	309	2·0	316	2·2	323	2·3	329	2·4	335	2·5	341	2·5	348	2·6	354	2·6	360	2·6
1·7	308	2·1	315	2·3	322	2·4	328	2·5	335	2·6	341	2·6	347	2·7	354	2·7	360	2·7
1·8	306	2·2	314	2·3	321	2·5	327	2·6	334	2·7	341	2·7	347	2·8	354	2·8	360	2·8
1·9	305	2·3	313	2·4	320	2·6	327	2·7	333	2·7	340	2·8	347	2·9	353	2·9	360	2·9
2·0	304	2·4	312	2·5	319	2·7	326	2·8	333	2·8	340	2·9	346	3·0	353	3·0	360	3·0
2·1	303	2·5	311	2·6	318	2·8	326	2·8	333	2·9	340	3·0	346	3·1	353	3·1	360	3·1
2·2	302	2·6	310	2·7	318	2·8	325	2·9	332	3·0	339	3·1	346	3·2	353	3·2	360	3·2
2·3	302	2·7	310	2·8	317	2·9	325	3·0	332	3·1	339	3·2	346	3·3	353	3·3	360	3·3
2·4	301	2·8	309	2·9	317	3·0	324	3·1	331	3·2	339	3·3	346	3·4	353	3·4	360	3·4
2·5	300	2·9	308	3·0	316	3·1	324	3·2	331	3·3	338	3·4	346	3·5	353	3·5	360	3·5
2·6	299	3·0	308	3·1	316	3·2	323	3·3	331	3·4	338	3·5	345	3·6	353	3·6	360	3·6
2·7	299	3·0	307	3·2	315	3·3	323	3·4	330	3·5	338	3·6	345	3·7	353	3·7	360	3·7
2·8	298	3·1	307	3·3	315	3·4	322	3·5	330	3·6	338	3·7	345	3·8	353	3·8	360	3·8
2·9	298	3·2	306	3·4	314	3·5	322	3·6	330	3·7	337	3·8	345	3·9	352	3·9	360	3·9
3·0	297	3·3	306	3·5	314	3·6	322	3·7	330	3·8	337	3·9	345	4·0	352	4·0	360	4·0
3·1	297	3·4	305	3·6	314	3·7	322	3·8	329	3·9	337	4·0	345	4·1	352	4·1	360	4·1
3·2	296	3·5	305	3·7	313	3·8	321	3·9	329	4·0	337	4·1	345	4·2	252	4·2	360	4·2
3·3	296	3·6	304	3·8	313	3·9	321	4·0	329	4·1	337	4·2	345	4·3	352	4·3	360	4·3
3·4	295	3·7	304	3·9	312	4·0	321	4·1	329	4·2	337	4·3	344	4·4	352	4·4	360	4·4
3·5	295	3·8	304	4·0	312	4·1	320	4·2	329	4·3	337	4·4	344	4·5	352	4·5	360	4·5
3·6	295	3·9	303	4·1	312	4·2	320	4·3	328	4·4	336	4·5	344	4·6	352	4·6	360	4·6
3·7	294	4·0	303	4·2	312	4·3	320	4·4	328	4·5	336	4·6	344	4·7	352	4·7	360	4·7
3·8	294	4·1	303	4·3	311	4·4	320	4·5	328	4·6	336	4·7	344	4·8	352	4·8	360	4·8
3·9	294	4·2	302	4·4	311	4·5	320	4·6	328	4·7	336	4·8	344	4·9	352	4·9	360	4·9
4·0	293	4·3	302	4·4	311	4·6	319	4·7	328	4·8	336	4·9	344	5·0	352	5·0	360	5·0
4·2	293	4·5	302	4·6	310	4·8	319	4·9	327	5·0	336	5·1	344	5·2	352	5·2	360	5·2
4·4	292	4·7	301	4·8	310	5·0	319	5·1	327	5·2	335	5·3	344	5·4	352	5·4	360	5·4
4·6	292	4·9	301	5·0	310	5·2	318	5·3	327	5·4	335	5·5	343	5·6	352	5·6	360	5·6
4·8	291	5·1	300	5·2	309	5·4	318	5·5	327	5·6	335	5·7	343	5·8	352	5·8	360	5·8
5·0	291	5·3	300	5·4	309	5·6	318	5·7	326	5·8	335	5·9	343	6·0	352	6·0	360	6·0
5·2	290	5·5	300	5·6	309	5·8	317	5·9	326	6·0	335	6·1	343	6·2	352	6·2	360	6·2
5·4	290	5·7	299	5·8	308	6·0	317	6·1	326	6·2	335	6·3	343	6·4	352	6·4	360	6·4
5·6	290	5·9	299	6·0	308	6·2	317	6·3	326	6·4	334	6·5	343	6·6	352	6·6	360	6·6
5·8	289	6·1	299	6·2	308	6·4	317	6·5	326	6·6	334	6·7	343	6·8	351	6·8	360	6·8
6·0	289	6·3	298	6·4	308	6·6	316	6·7	325	6·8	334	6·9	343	7·0	351	7·0	360	7·0
6·5	288	6·8	298	6·9	307	7·1	316	7·2	325	7·3	334	7·4	343	7·5	351	7·5	360	7·5
7·0	288	7·3	297	7·4	306	7·6	316	7·7	325	7·8	334	7·9	342	8·0	351	8·0	360	8·0
7·5	287	7·8	297	7·9	306	8·1	316	8·2	324	8·3	333	8·4	342	8·5	351	8·5	360	8·5
8·0	287	8·2	296	8·4	306	8·6	315	8·7	324	8·8	333	8·9	342	9·0	351	9·0	360	9·0
8·5	286	8·7	296	8·9	305	9·1	315	9·2	324	9·3	333	9·4	342	9·5	351	9·5	360	9·5
9·0	286	9·2	296	9·4	305	9·5	314	9·7	324	9·8	333	9·9	342	10·0	351	10·0	360	10·0
9·5	286	9·7	295	9·9	305	10·0	314	10·2	324	10·3	333	10·4	342	10·5	351	10·5	360	10·5
10·0	285	10·2	295	10·4	305	10·5	314	10·7	323	10·8	333	10·9	342	11·0	351	11·0	360	11·0

If *d* is negative, *e* is negative.

TABLE 4.—*l*, *L*

For combining Tides of Different Species (Semidiurnal and Diurnal).

J \ j	0·0		0·5		1·0		1·5		2·0		2·5		3·0		3·5		4·0	
	l	L	*l*	L	*l*	L	*l*	L	*l*	L	*l*	L	*l*	L	*l*	L	*l*	L
0·0	0·0 6·0 12·0 18·0	1·0 −1·0 1·0 −1·0	0·0 6·0 12·0 18·0	1·0 −1·0 1·0 −1·0	0·0 6·0 12·0 18·0	1·0 −1·0 1·0 −1·0	0·0 6·0 12·0 18·0	1·0 −1·0 1·0 −1·0	0·0 6·0 12·0 18·0	1·0 −1·0 1·0 −1·0	0·0 6·0 12·0 18·0	1·0 −1·0 1·0 −1·0	0·0 6·0 12·0 18·0	1·0 −1·0 1·0 −1·0	0·0 6·0 12·0 18·0	1·0 −1·0 1·0 −1·0	0·0 6·0 12·0 18·0	1·0 −1·0 1·0 −1·0
0·2	0·0 0·2 12·0 17·8	1·2 −1·0 0·8 −1·0	0·0 6·2 12·0 17·8	1·2 −1·0 0·8 −1·0	0·0 6·2 11·9 17·8	1·2 −1·0 0·8 −1·1	0·1 6·2 11·9 17·8	1·2 −0·9 0·8 −1·1	0·1 6·2 11·9 17·8	1·2 −0·9 0·8 −1·1	0·1 6·2 11·9 17·9	1·2 −0·9 0·8 −1·1	0·1 6·1 11·9 17·9	1·1 −0·9 0·9 −1·1	0·1 0·1 11·8 17·9	1·1 −0·8 0·9 −1·2	0·2 6·1 11·8 17·9	1·1 −0·8 0·9 −1·2

J \ j	4·0		4·5		5·0		5·5		0·0		6·5		7·0		7·5		8·0	
	l	L	*l*	L	*l*	L	*l*	L	*l*	L	*l*	L	*l*	L	*l*	L	*l*	L
0·0	0·0 6·0 12·0 18·0	1·0 −1·0 1·0 −1·0	0·0 6·0 12·0 18·0	1·0 −1·0 1·0 −1·0	0·0 6·0 12·0 18·0	1·0 −1·0 1·0 −1·0	0·0 6·0 12·0 18·0	1·0 −1·0 1·0 −1·0	0·0 6·0 12·0 18·0	1·0 −1·0 1·0 −1·0	0·0 6·0 12·0 18·0	1·0 −1·0 1·0 −1·0	0·0 6·0 12·0 18·0	1·0 −1·0 1·0 −1·0	0·0 6·0 12·0 18·0	1·0 −1·0 1·0 −1·0	0·0 6·0 12·0 18·0	1·0 −1·0 1·0 −1·0
0·2	0·2 6·1 11·8 17·9	1·1 −0·8 0·9 −1·2	0·2 6·1 11·8 17·9	1·1 −0·8 0·9 −1·2	0·2 0·1 11·8 18·0	1·1 −0·8 1·0 −1·2	0·2 6·0 11·8 18·0	1·0 −0·8 1·0 −1·2	0·2 6·0 11·8 18·0	1·0 −0·8 1·0 −1·2	0·2 6·0 11·8 18·0	1·0 −0·8 1·0 −1·2	0·2 5·9 11·8 18·1	1·0 −0·8 1·1 −1·2	0·2 5·9 11·8 18·1	0·9 −0·8 1·1 −1·2	0·2 5·9 11·8 18·1	0·9 −0·8 1·1 −1·2
0·4							0·4 6·1 11·6 18·0	1·1 −0·6 1·0 −1·4	0·4 6·0 11·6 18·0	1·0 −0·6 1·0 −1·4								

J \ j	8·0		8·5		9·0		9·5		10·0		10·5		11·0		11·5		12·0	
0·0	0·0 6·0 12·0 18·0	1·0 −1·0 1·0 −1·0	0·0 6·0 12·0 18·0	1·0 −1·0 1·0 −1·0	0·0 6·0 12·0 18·0	1·0 −1·0 1·0 −1·0	0·0 6·0 12·0 18·0	1·0 −1·0 1·0 −1·0	0·0 6·0 12·0 18·0	1·0 −1·0 1·0 −1·0	0·0 6·0 12·0 18·0	1·0 −1·0 1·0 −1·0	0·0 6·0 12·0 18·0	1·0 −1·0 1·0 −1·0	0·0 6·0 12·0 18·0	1·0 −1·0 1·0 −1·0	0·0 6·0 12·0 18·0	1·0 −1·0 1·0 −1·0
0·2	0·2 −5·9 11·8 18·1	0·9 −0·8 1·1 −1·2	0·2 5·9 11·9 18·1	0·9 −0·8 1·1 −1·2	0·1 5·9 11·9 18·1	0·9 −0·9 1·1 −1·1	0·1 5·8 11·9 18·1	0·8 −0·9 1·2 −1·1	0·1 5·8 11·9 18·2	0·8 −0·9 1·2 −1·1	0·1 5·8 11·9 18·2	0·8 −0·9 1·2 −1·1	0·1 5·8 12·0 18·2	0·8 −1·0 1·2 −1·1	0·0 5·8 12·0 18·2	0·8 −1·0 1·2 −1·0	0·0 5·8 12·0 18·2	0·8 −1·0 1·2 −1·0

J \ j	12·0		12·5		13·0		13·5		14·0		14·5		15·0		15·5		16·0	
0·0	6·0 12·0 18·0 24·0	−1·0 1·0 −1·0 1·0	6·0 12·0 18·0 24·0	−1·0 1·0 −1·0 1·0	6·0 12·0 18·0 24·0	−1·0 1·0 −1·0 1·0	6·0 12·0 18·0 24·0	−1·0 1·0 −1·0 1·0	6·0 12·0 18·0 24·0	−1·0 1·0 −1·0 1·0	6·0 12·0 18·0 24·0	−1·0 1·0 −1·0 1·0	6·0 12·0 18·0 24·0	−1·0 1·0 −1·0 1·0	6·0 12·0 18·0 24·0	−1·0 1·0 −1·0 1·0	6·0 12·0 18·0 24·0	−1·0 1·0 −1·0 1·0
0·2	5·8 12·0 18·2 24·0	−1·0 1·2 −1·0 0·8	5·8 12·0 18·2 21·0	−1·0 1·2 −1·0 0·8	5·8 12·1 18·2 24·0	−1·1 1·2 −1·0 0·8	5·8 12·1 18·2 23·9	−1·1 1·2 −0·9 0·8	5·8 12·1 18·2 23·9	−1·1 1·2 −0·9 0·8	5·9 12·1 18·2 23·9	−1·1 1·2 −0·9 0·8	5·9 12·1 18·1 23·9	−1·1 1·1 −0·9 0·9	5·9 12·1 18·1 23·8	−1·2 1·1 −0·8 0·9	5·9 12·2 18·1 23·8	−1·2 1·1 −0·8 0·9

TABLE 4—*l*, L—*contd.*

For combining Tides of Different Species (Semidiurnal and Diurnal).

J \ j	16·0		16·5		17·0		17·5		18·0		18·5		19·0		19·5		20·0	
	l	L	*l*	L	*l*	L	*l*	L	*l*	L	*l*	L	*l*	L	*l*	L	*l*	L
0·0	6·0 12·0 18·0 24·0	−1·0 1·0 −1·0 1·0	6·0 12·0 18·0 24·0	−1·0 1·0 −1·0 1·0	6·0 12·0 18·0 24·0	−1·0 1·0 −1·0 1·0	6·0 12·0 18·0 24·0	−1·0 1·0 −1·0 1·0	6·0 12·0 18·0 24·0	−1·0 1·0 −1·0 1·0	6·0 12·0 18·0 24·0	−1·0 1·0 −1·0 1·0	6·0 12·0 18·0 24·0	−1·0 1·0 −1·0 1·0	6·0 12·0 18·0 24·0	−1·0 1·0 −1·0 1·0	6·0 12·0 18·0 24·0	−1·0 1·0 −1·0 1·0
0·2	5·9 12·2 18·1 23·8	−1·2 1·1 −0·8 0·9	5·9 12·2 18·1 23·8	−1·2 1·1 −0·8 0·9	6·0 12·2 18·1 23·8	−1·2 1·1 −0·8 1·0	6·0 12·2 18·0 23·8	−1·2 1·0 −0·8 1·0	6·0 12·2 18·0 23·8	−1·2 1·0 −0·8 1·0	6·0 12·2 18·0 23·8	−1·2 1·0 −0·8 1·0	6·1 12·2 17·9 23·8	−1·2 1·0 −0·8 1·1	6·1 12·2 17·9 23·8	−1·2 0·9 −0·8 1·1	6·1 12·2 17·9 23·8	−1·2 0·9 −0·8 1·1

J \ j	20·0		20·5		21·0		21·5		22·0		22·5		23·0		23·5		24·0	
0·0	6·0 12·0 18·0 24·0	−1·0 1·0 −1·0 1·0	6·0 12·0 18·0 24·0	−1·0 1·0 −1·0 1·0	6·0 12·0 18·0 24·0	−1·0 1·0 −1·0 1·0	6·0 12·0 18·0 24·0	−1·0 1·0 −1·2 1·0	6·0 12·0 18·0 24·0	−1·0 1·0 −1·0 1·0	6·0 12·0 18·0 24·0	−1·0 1·0 −1·0 1·0	6·0 12·0 18·0 24·0	−1·0 1·0 −1·0 1·0	6·0 12·0 18·0 24·0	−1·0 1·0 −1·0 1·0	6·0 12·0 18·0 24·0	−1·0 1·0 −1·0 1·0
0·2	6·1 12·2 17·9 23·8	−1·2 0·9 −0·8 1·1	6·1 12·2 17·9 23·9	−1·2 0·9 −0·8 1·1	6·1 12·1 17·9 23·9	−1·1 0·9 −0·9 1·1	6·1 12·1 17·8 23·9	−1·1 0·8 −0·9 1·2	6·2 12·1 17·8 23·9	−1·1 0·8 −0·9 1·2	6·2 12·1 17·8 23·9	−1·1 0·8 −0·9 1·2	6·2 12·1 17·8 24·0	−1·1 0·8 −1·0 1·2	6·2 12·0 17·8 24·0	−1·0 0·8 −1·0 1·2	6·2 12·0 17·8 24·0	−1·0 0·8 −1·0 1·2

J \ j				
3·0	8·1 — — 23·4	−2·9 — — 3·9	8·4 — — 23·6	−2·6 — — 3·9
3·2	8·2 — — 23·3	−3·0 — — 4·1	8·5 — — 23·6	−2·8 — — 4·1
3·4	8·3 — — 23·3	−3·2 — — 4·3	8·6 — — 23·5	−3·0 — — 4·3
3·6	8·4 — — 23·3	−3·4 — — 4·5	8·8 — — 23·5	−3·1 — — 4·5
3·8	8·5 23·3	−3·6 4·6	8·9 23·5	−3·3 4·7

TABLE 5—Period Corrections.

Corrections in minute per Mean Solar Hour.

	S_2 Corrections									K_1 Corrections								
D \ d	0° 360	90° 270	120° 240	130° 230	140° 220	150° 210	160° 200	170° 190	180° 180	0° 360	90° 270	120° 240	130° 230	140° 220	150° 210	160° 200	170° 190	180° 180
0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0
0·1	0·2	0·0	−0·1	−0·1	−0·2	−0·2	−0·2	−0·2	−0·2	0·4	0·0	−0·2	−0·2	−0·3	−0·4	−0·4	−0·4	−0·4
0·2	0·3	0·1	−0·1	−0·2	−0·3	−0·4	−0·5	−0·5	−0·4	0·7	0·2	−0·2	−0·4	−0·7	−0·9	−1·0	−1·1	−0·9
0·3	0·4	0·2	−0·1	−0·3	−0·5	−0·6	−0·7	−0·8	−0·8	0·9	0·4	−0·3	−0·6	−1·0	−1·3	−1·5	−1·8	−1·8
0·4	0·5	0·3	−0·2	−0·3	−0·5	−0·8	−1·0	−1·2	−1·4	1·1	0·7	−0·4	−0·7	−1·1	−1·8	−2·2	−2·6	−3·1
0·5	0·6	0·4	−0·1	−0·2	−0·5	−1·0	−1·4	−1·8	−2·0	1·3	0·9	−0·2	−0·5	−1·1	−2·2	−3·1	−4·0	−4·4
0·6	0·7	0·5	0·2	−0·1	−0·5	−1·1	−1·8	−2·5	−2·9	1·5	1·1	0·3	−0·2	−1·0	−2·4	−4·0	−5·5	−6·2
0·7	0·8	0·6	0·3	0·1	−0·2	−1·1	−1·9	−3·6	−4·3	1·8	1·3	0·8	0·2	−0·4	−2·4	−4·2	−7·7	−9·3
0·8	0·9	0·7	0·6	0·4	0·1	−0·5	−2·0	−4·9	−6·7	2·0	1·5	1·3	0·9	0·4	−1·1	−4·4	−10·6	−14·6
0·9	1·0	0·8	0·8	0·7	0·5	0·1	−1·0	−6·4	−11·0	2·2	1·8	1·8	1·5	1·1	0·2	−2·2	−14·0	−23·9
1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	—	—	2·3	2·2	2·2	2·2	2·2	2·2	2·2	—	—
1·1	1·1	1·1	1·2	1·2	1·4	1·8	2·9	8·7	13·7	2·4	2·4	2·6	2·7	3·1	4·0	6·2	18·8	29·5
1·2	1·1	1·2	1·4	1·5	1·8	2·3	3·8	7·5	10·0	2·5	2·6	3·0	3·3	4·0	5·1	8·2	16·0	21·6
1·3	1·2	1·3	1·5	1·7	2·0	2·8	4·1	6·4	8·0	2·6	2·8	3·3	3·8	4·4	5·7	8·8	13·9	17·0
1·4	1·2	1·3	1·6	1·9	2·2	2·9	4·1	5·8	6·7	2·5	2·9	3·5	4·2	4·8	6·2	8·8	12·6	14·6
1·5	1·2	1·3	1·7	2·0	2·4	3·1	4·0	5·2	5·9	2·7	3·0	3·8	4·4	5·3	6·6	8·6	11·2	12·8
1·6	1·2	1·4	1·8	2·1	2·5	3·2	3·9	4·8	5·3	2·7	3·1	4·0	4·6	5·4	6·8	8·4	10·3	11·5
1·7	1·3	1·4	1·9	2·2	2·5	3·1	3·8	4·5	4·9	2·8	3·2	4·2	4·7	5·5	6·7	8·2	9·7	10·6
1·8	1·3	1·5	2·0	2·2	2·5	3·1	3·7	4·3	4·5	2·9	3·3	4·3	4·7	5·5	6·6	7·0	9·3	9·7
1·9	1·3	1·5	2·0	2·2	2·5	3·1	3·6	4·1	4·3	3·0	3·4	4·4	4·8	5·6	6·6	7·7	8·8	9·3
2·0	1·4	1·6	2·1	2·2	2·5	3·1	3·5	3·9	4·1	3·1	3·5	4·5	4·8	5·6	6·5	7·4	8·4	8·8
2·2	1·4	1·6	2·1	2·3	2·6	3·0	3·3	3·6	3·7	3·1	3·6	4·6	4·9	5·7	6·4	7·1	7·7	7·9
2·4	1·4	1·7	2·1	2·3	2·6	2·9	3·2	3·4	3·5	3·2	3·7	4·7	5·0	5·7	6·2	6·8	7·3	7·5
2·6	1·5	1·7	2·2	2·3	2·5	2·8	3·1	3·3	3·3	3·2	3·8	4·8	5·1	5·6	6·0	6·6	7·0	7·1
2·8	1·5	1·7	2·2	2·3	2·5	2·8	3·0	3·1	3·1	3·3	3·9	4·8	5·2	5·6	5·9	6·4	6·6	6·9
3·0	1·5	1·8	2·2	2·3	2·5	2·8	2·9	3·0	3·1	3·4	3·9	4·8	5·2	5·5	5·8	6·3	6·4	6·6
3·2	1·5	1·8	2·1	2·3	2·5	2·7	2·9	3·0	3·0	3·4	4·0	4·7	5·1	5·5	5·7	6·1	6·3	6·4
3·4	1·6	1·8	2·1	2·3	2·5	2·7	2·8	2·9	2·9	3·5	4·1	4·7	5·1	5·5	5·7	5·9	6·2	6·2
3·6	1·6	1·9	2·1	2·3	2·5	2·7	2·7	2·8	2·9	3·5	4·2	4·7	5·1	5·4	5·6	5·8	6·0	6·0
3·8	1·6	1·9	2·1	2·3	2·4	2·6	2·7	2·8	2·9	3·6	4·2	4·6	5·1	5·4	5·5	5·7	5·9	5·8
4·0	1·6	1·9	2·1	2·3	2·4	2·6	2·7	2·7	2·8	3·6	4·2	4·6	5·1	5·3	5·5	5·6	5·7	5·7
4·4	1·6	1·9	2·1	2·3	2·4	2·5	2·6	2·6	2·7	3·7	4·3	4·6	5·1	5·3	5·4	5·5	5·6	5·7
4·8	1·6	1·9	2·1	2·3	2·3	2·4	2·6	2·6	2·7	3·7	4·3	4·6	5·0	5·2	5·3	5·5	5·5	5·6
5·2	1·7	1·9	2·1	2·3	2·3	2·4	2·5	2·5	2·6	3·8	4·3	4·6	5·0	5·1	5·2	5·4	5·4	5·5
5·6	1·7	1·9	2·1	2·3	2·3	2·3	2·4	2·4	2·5	3·8	4·3	4·6	4·9	5·1	5·1	5·3	5·3	5·4
6·0	1·7	1·9	2·1	2·3	2·3	2·3	2·4	2·4	2·5	3·9	4·3	4·6	4·9	5·0	5·1	5·3	5·3	5·3
6·5	1·7	2·0	2·1	2·3	2·3	2·3	2·3	2·4	2·4	3·9	4·3	4·6	4·8	5·0	5·0	5·2	5·2	5·3
7·0	1·8	2·0	2·1	2·2	2·3	2·3	2·3	2·3	2·4	4·0	4·4	4·6	4·8	4·9	5·0	5·1	5·1	5·2
7·5	1·8	2·0	2·1	2·2	2·2	2·2	2·3	2·3	2·3	4·0	4·4	4·6	4·7	4·9	4·9	5·1	5·1	5·2
8·0	1·8	2·0	2·1	2·2	2·2	2·2	2·3	2·3	2·3	4·0	4·4	4·6	4·7	4·8	4·9	5·0	5·0	5·1
8·5	1·8	2·0	2·1	2·2	2·2	2·2	2·2	2·3	2·3	4·0	4·4	4·6	4·6	4·8	4·8	4·9	5·0	5·0
9·0	1·8	2·0	2·1	2·2	2·2	2·2	2·2	2·2	2·2	4·0	4·4	4·6	4·6	4·8	4·8	4·8	4·9	4·9
9·5	1·8	2·0	2·1	2·2	2·2	2·2	2·2	2·2	2·2	4·0	4·4	4·6	4·6	4·8	4·8	4·8	4·8	4·8
10·0	1·8	2·0	2·1	2·2	2·2	2·2	2·2	2·2	2·2	4·0	4·4	4·6	4·6	4·8	4·8	4·8	4·8	4·8

Sign of correction does not change if *d* is negative.

$$\text{Correction} = \text{Interval from 12h. (or special hour)} \times \frac{(S_2 \text{ corr.} \times F_2) + (K_1 \text{ corr.} \times F_1)}{F_2 + F_1}$$

Correction is to be applied according to sign to times after, with sign reversed to times before, 12h. (or special hour).

Note.—When D = 1·0 and *d* = 180°, range of lunar and solar tides are equal and lunar high water coincides with solar low water; consequently there is no tide. When D is nearly 1·0 and *d* nearly 180°, there is very little tide; consequently times of high and low water are uncertain.

TABLE 6.—D cos d'. Height of Constituent according to Phase.

d' \ D	D cos d' negative			0				1					2					3					4					5					6
°	°	°	°	0·2	0·4	0·6	0·8	0·0	0·2	0·4	0·6	0·8	0·0	0·2	0·4	0·6	0·8	0·0	0·2	0·4	0·6	0·8	0·0	0·2	0·4	0·6	0·8	0·0	0·2	0·4	0·6	0·8	0·0
000	180	180	360	0·2	0·4	0·6	0·8	1·0	1·2	1·4	1·6	1·8	2·0	2·2	2·4	2·6	2·8	3·0	3·2	3·4	3·6	3·8	4·0	4·2	4·4	4·6	4·8	5·0	5·2	5·4	5·6	5·8	6·0
010	170	190	350	0·2	0·4	0·6	0·8	1·0	1·2	1·4	1·6	1·8	2·0	2·2	2·4	2·6	2·8	3·0	3·1	3·3	3·5	3·7	3·9	4·1	4·3	4·5	4·7	4·9	5·1	5·3	5·5	5·7	5·9
015	165	195	345	0·2	0·4	0·6	0·8	1·0	1·2	1·4	1·5	1·7	1·9	2·1	2·3	2·5	2·7	2·9	3·1	3·2	3·5	3·6	3·9	4·0	4·2	4·4	4·6	4·8	5·0	5·2	5·4	5·6	5·8
020	160	200	340	0·2	0·4	0·6	0·8	0·9	1·1	1·3	1·5	1·7	1·9	2·1	2·3	2·4	2·6	2·8	3·0	3·2	3·4	3·6	3·8	3·9	4·1	4·3	4·5	4·7	4·9	5·1	5·3	5·4	5·6
025	155	205	335	0·2	0·4	0·5	0·7	0·9	1·1	1·3	1·4	1·6	1·8	2·0	2·2	2·3	2·5	2·7	2·9	3·1	3·3	3·5	3·6	3·8	4·0	4·2	4·4	4·5	4·7	4·9	5·1	5·2	5·4
030	150	210	330	0·2	0·4	0·5	0·7	0·9	1·0	1·2	1·4	1·6	1·8	1·9	2·1	2·2	2·4	2·6	2·8	3·0	3·1	3·3	3·5	3·7	3·8	4·0	4·2	4·3	4·5	4·7	4·9	5·0	5·2
032	148	212	328	0·2	0·3	0·5	0·7	0·8	1·0	1·2	1·4	1·5	1·7	1·9	2·0	2·2	2·4	2·5	2·7	2·9	3·0	3·2	3·4	3·6	3·7	3·9	4·1	4·2	4·4	4·6	4·7	4·9	5·1
034	146	214	326	0·2	0·3	0·5	0·7	0·8	1·0	1·2	1·3	1·5	1·7	1·8	2·0	2·1	2·3	2·5	2·6	2·8	2·9	3·1	3·3	3·5	3·6	3·8	4·0	4·1	4·3	4·5	4·6	4·8	5·0
036	144	216	324	0·2	0·3	0·5	0·6	0·8	1·0	1·1	1·3	1·5	1·6	1·8	1·9	2·1	2·3	2·4	2·6	2·7	2·9	3·1	3·2	3·4	3·5	3·7	3·9	4·0	4·2	4·4	4·5	4·7	4·9
038	142	218	322	0·2	0·3	0·5	0·6	0·8	0·9	1·1	1·2	1·4	1·6	1·7	1·9	2·0	2·2	2·4	2·5	2·7	2·8	3·0	3·1	3·3	3·5	3·6	3·8	3·9	4·1	4·3	4·4	4·6	4·8
040	140	220	320	0·2	0·3	0·5	0·6	0·8	0·9	1·1	1·2	1·4	1·5	1·7	1·8	2·0	2·1	2·3	2·5	2·6	2·8	2·9	3·1	3·2	3·4	3·5	3·7	3·8	4·0	4·1	4·3	4·4	4·6
042	138	222	318	0·1	0·3	0·4	0·6	0·7	0·9	1·0	1·1	1·3	1·5	1·6	1·8	1·9	2·1	2·2	2·4	2·5	2·7	2·8	3·0	3·1	3·3	3·4	3·6	3·7	3·9	4·0	4·2	4·3	4·4
044	136	224	316	0·1	0·3	0·4	0·6	0·7	0·9	1·0	1·1	1·3	1·4	1·6	1·7	1·9	2·0	2·2	2·3	2·4	2·6	2·7	2·9	3·0	3·2	3·3	3·4	3·6	3·7	3·9	4·0	4·2	4·3
046	134	226	314	0·1	0·3	0·4	0·6	0·7	0·8	1·0	1·1	1·2	1·4	1·5	1·7	1·8	1·9	2·1	2·2	2·4	2·5	2·6	2·8	2·9	3·1	3·2	3·3	3·5	3·6	3·8	3·9	4·0	4·1
048	132	228	312	0·1	0·3	0·4	0·5	0·7	0·8	0·9	1·0	1·2	1·3	1·5	1·6	1·7	1·9	2·0	2·1	2·3	2·4	2·5	2·7	2·8	2·9	3·1	3·2	3·3	3·5	3·6	3·7	3·9	4·0
050	130	230	310	0·1	0·3	0·4	0·5	0·6	0·8	0·9	1·0	1·1	1·3	1·4	1·5	1·7	1·8	1·9	2·1	2·2	2·3	2·4	2·6	2·7	2·8	3·0	3·1	3·2	3·3	3·5	3·6	3·7	3·8
052	128	232	308	0·1	0·2	0·4	0·5	0·6	0·7	0·9	1·0	1·1	1·2	1·4	1·5	1·6	1·7	1·9	2·0	2·1	2·2	2·3	2·5	2·6	2·7	2·8	3·0	3·1	3·2	3·3	3·4	3·6	3·7
054	126	234	306	0·1	0·2	0·4	0·5	0·6	0·7	0·8	0·9	1·1	1·2	1·3	1·4	1·5	1·6	1·8	1·9	2·0	2·1	2·2	2·3	2·5	2·6	2·7	2·8	2·9	3·1	3·2	3·3	3·4	3·5
056	124	236	304	0·1	0·2	0·3	0·4	0·6	0·7	0·8	0·9	1·0	1·1	1·2	1·3	1·5	1·6	1·7	1·8	1·9	2·0	2·1	2·2	2·3	2·5	2·6	2·7	2·8	2·9	3·0	3·1	3·2	3·4
058	122	238	302	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	1·0	1·1	1·2	1·3	1·4	1·5	1·6	1·7	1·8	1·9	2·0	2·1	2·2	2·3	2·4	2·5	2·6	2·8	2·9	3·0	3·1	3·2
060	120	240	300	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9	1·0	1·1	1·2	1·3	1·4	1·5	1·6	1·7	1·8	1·9	2·0	2·1	2·2	2·3	2·4	2·5	2·6	2·7	2·8	2·9	3·0
062	118	242	298	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·8	0·9	1·0	1·1	1·2	1·3	1·4	1·5	1·6	1·7	1·8	1·9	2·0	2·1	2·2	2·3	2·4	2·5	2·5	2·6	2·7	2·8
064	116	244	296	0·1	0·2	0·3	0·4	0·4	0·5	0·6	0·7	0·8	0·9	1·0	1·1	1·1	1·2	1·3	1·4	1·5	1·6	1·7	1·8	1·8	1·9	2·0	2·1	2·2	2·3	2·4	2·5	2·5	2·6
066	114	246	294	0·1	0·2	0·3	0·3	0·4	0·5	0·6	0·7	0·7	0·8	0·9	1·0	1·1	1·2	1·2	1·3	1·4	1·5	1·6	1·6	1·7	1·8	1·9	2·0	2·1	2·2	2·2	2·3	2·4	2·5
068	112	248	292	0·1	0·2	0·2	0·3	0·4	0·5	0·5	0·6	0·7	0·7	0·8	0·9	1·0	1·1	1·1	1·2	1·3	1·4	1·4	1·5	1·6	1·7	1·7	1·8	1·9	2·0	2·0	2·1	2·2	2·3
070	110	250	290	0·1	0·1	0·2	0·3	0·3	0·4	0·5	0·5	0·6	0·7	0·8	0·8	0·9	1·0	1·0	1·1	1·2	1·2	1·3	1·4	1·4	1·5	1·6	1·6	1·7	1·8	1·8	1·9	2·0	2·1
072	108	252	288	0·1	0·1	0·2	0·2	0·3	0·4	0·4	0·5	0·6	0·6	0·7	0·7	0·8	0·9	0·9	1·0	1·1	1·1	1·2	1·2	1·3	1·4	1·4	1·5	1·5	1·6	1·7	1·7	1·8	1·9
074	106	254	286	0·1	0·1	0·2	0·2	0·3	0·3	0·4	0·4	0·5	0·6	0·6	0·7	0·7	0·8	0·8	0·9	0·9	1·0	1·1	1·1	1·2	1·2	1·3	1·3	1·4	1·4	1·5	1·5	1·6	1·7
076	104	256	284	0·0	0·1	0·1	0·2	0·2	0·3	0·3	0·4	0·4	0·5	0·5	0·6	0·6	0·7	0·7	0·8	0·8	0·9	0·9	1·0	1·0	1·1	1·1	1·2	1·2	1·3	1·3	1·4	1·4	1·5
078	102	258	282	0·0	0·1	0·1	0·2	0·2	0·3	0·3	0·3	0·4	0·4	0·5	0·5	0·5	0·6	0·6	0·7	0·7	0·7	0·8	0·8	0·9	0·9	1·0	1·0	1·0	1·1	1·1	1·2	1·2	1·3
080	100	260	280	0·0	0·1	0·1	0·1	0·2	0·2	0·2	0·3	0·3	0·3	0·4	0·4	0·5	0·5	0·5	0·6	0·6	0·6	0·6	0·7	0·7	0·8	0·8	0·8	0·9	0·9	0·9	1·0	1·0	1·0
082	098	262	278	0·0	0·1	0·1	0·1	0·1	0·2	0·2	0·2	0·3	0·3	0·3	0·3	0·4	0·4	0·4	0·4	0·5	0·5	0·5	0·6	0·6	0·6	0·6	0·7	0·7	0·7	0·8	0·8	0·8	0·8
084	096	264	276	0·0	0·0	0·1	0·1	0·1	0·1	0·1	0·2	0·2	0·2	0·2	0·3	0·3	0·3	0·3	0·3	0·4	0·4	0·4	0·4	0·4	0·5	0·5	0·5	0·5	0·5	0·6	0·6	0·6	0·6
086	094	266	274	0·0	0·0	0·0	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·2	0·2	0·2	0·2	0·2	0·2	0·2	0·3	0·3	0·3	0·3	0·3	0·3	0·3	0·4	0·4	0·4	0·4	0·4	0·4
088	092	268	272	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·2	0·2	0·2	0·2	0·2	0·2	0·2	0·2	0·2
090	090	270	270	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0

Note.—D cos d' is negative when d' is between 090° and 270°.

Form A. TO FIND TIMES AND HEIGHTS OF HIGH AND LOW WATER

Place : Date :

A_0 or Mean Sea Level : ft. (from A.T.T. Part II)

Seasonal Correction : ,, ,, ,, ,,

Corrected Mean Sea Level : ,,

* A.M. Moon's Transit : (from A.T.T. Part II)

Increment : + 24 min.

Adjusted Transit :

Moon's H.P. : (from A.T.T. Part II)

	M_2	S_2	K_1	O_1
(1) Harmonic Constants from A.T.T. Part II ..	g ° H ft.	g ° H ft.	g ° H ft.	g ° H ft.
(2) Enter Table 1 with year and date	b ° B	b ° B	b ° B	b ° B
(3) Enter Table 2 with Adjusted Transit and H.P.	c ° C	— — — —	— — C	c ° C
(4) Add $(g+b+c)$; Multiply $(H \times B \times C)$	m ° M ft.	s ° S ft.	k ° K ft.	o ° O ft.
	SEMIDIURNAL TIDE		DIURNAL TIDE	
(5) From Line (4) { Add or subtract 360° or 720° if necessary	$d_2 = m - s$; $D_2 = \frac{M}{S}$	d_2 ° D_2 ft.	d_1 ° D_1 ft.	$d_1 = o - k$; $D_1 = \frac{O}{K}$
(6) Enter Table 3 with d and D from Line (5) ..		e_2 ° E_2	e_1 ° E_1	
(7) From Lines (6) and (4)	$f_2 = e_2 + s$; $F_2 = E_2 \times S$	f_2 ° F_2 ft.	f_1 ° F_1 ft.	$f_1 = e_1 + k$; $F_1 = E_1 \times K$
(8) Subtract 360° or 720° if necessary to reduce f_2, f_1 below 360°		f_2 ° —	f_1 ° —	
(9) *Convert f_2 and f_1 angles into time* : $\frac{f_2}{30}, \frac{f_1}{15}$ ..		f_2 hrs. —	f_1 hrs. —	

COMBINED SEMIDIURNAL AND DIURNAL TIDE

(10) From Line (9)	$j = (f_1 - f_2)$ hrs.; add 24 hrs. if negative	j hrs.				
(10) From Line (7)	$J = \frac{F_1}{F_2}$	J				
(11) Enter Table 4 with j and J		Time (l)	hrs.	hrs.	hrs.	hrs.
		Factor (L)				
(12) From Lines (11) and (9)	$q = (l + f_2)$ hrs.	Time (q)	hrs.	hrs.	hrs.	hrs.
(12) From Lines (11) and (7)	$Q = (L \times F_2)$ ft.	Height (Q)	ft.	ft.	ft.	ft.
(13) **Times and Heights of High and Low Water** (Subtract 24 hrs. from times if necessary)	† q in hours and minutes	Time	h. m.	h. m.	h. m.	h. m.
	Q + Corrected Mean Sea Level	Height	ft.	ft.	ft.	ft.
(14) If special accuracy is required, enter Table (5) for S_2 with d_2 and D_2 from Line (5);		‡ Corrections	m.	m.	m.	m.
and enter Table 5 for K_1 with d_1 and D_1. Deduce corrections to Times		Corrd. Times	h. m.	h. m.	h. m.	h. m.

§ (15) Times from Line (14), Heights from Line (13)	h. m.	ft.	h. m.	ft.	h. m.	ft.	h. m.	ft.
Shallow Water Corrections (from A.T.T. Part II)								
(16) **Shallow Water Predictions**	h. m.	ft.	h. m.	ft.	h. m.	ft.	h. m.	ft.

Tables 1 to 5 will be found in A.T.T. Part III.

* A.M. Transit when there are two on the day, only transit when one.

† Tides from which 24 hours have been subtracted become first tides of the day.

‡ If correction per hour is positive, subtract from a.m., add to p.m. tides; if negative, add to a.m., subtract from p.m. tides. Total correction is: Correction per hour × interval from 1200.

§ This step will only be necessary if Shallow Water Corrections are given in A.T.T. Part II.

Form B. TO FIND THE HEIGHT OF THE TIDE AT ANY REQUIRED TIME

Place : Date :

Required Standard Time : $= t$ (hours and tenths)

A_o or Mean Sea Level : ft. (from A.T.T. Part II) * A.M. Moon's Transit : (from A.T.T. Part II)

Seasonal Correction : ,, ,, ,, ,, † Increment for t hours : + mins.

Corrected Mean Sea Level : ,, Adjusted Transit :

Moon's H.P. : (from A.T.T. Part II)

	M_2	S_2	K_1	O_1
(1) Harmonic Constants from A.T.T. Part II ..	g ° H ft.	g ° H ft.	g ° H ft.	g ° H ft.
(2) Enter Table 1 with year and date	b ° B	b ° B	b ° B	b ° B
(3) Enter Table 2 with Adjusted Transit and H.P.	c ° C	— — — —	— — C	c ° C
(4) Add $(g+b+c)$; Multiply $(H \times B \times C)$	m ° M ft.	s ° S ft.	k ° K ft.	o ° O ft
(5) Convert Required Standard Time into angle ..	$t \times 30 =$ $° = t_m$	$t \times 30 =$ $° = t_s$	$t \times 15 =$ $° = t_k$	$t \times 15 =$ $° = t_o$
(6) Line (5) (angle) minus Line (4) (angle).. ..	$t_m - m =$ $° = d_m$	$t_s - s =$ $° = d_s$	$t_k - k =$ $° = d_k$	$t_o - o =$ $° = d_o$
(7) Add or subtract 360° or 720°, where necessary to make line (6) between 0° and +360° ..	$d_m =$ °	$d_s =$ °	$d_k =$ °	$d_o =$ °
(8) Enter Table 6 with Heights from Line (4) and angles from Line (7)	ft.	ft.	ft.	ft.
Height of Tide = { Corrected Mean Sea Level + Sum of Heights in Line (8)				

Tables 1, 2 and 6 will be found in A.T.T. Part III.

* A.M. Transit when there are two on the day, only transit when one.

† Add 2 minutes for each hour of Required Standard Time, counting from 0000; *e.g.* if Required Time is 1630 ($t = 16 \cdot 5$) increment is +33 mins.